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# Environmental Assessment of Surface Mining Methods Head-of-Hollow Fill and Mountaintop Removal. Volume 2

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As a portion of the EPA study "Environmental Assessment of Head-of-Hollow Fill and Mountaintop Removal Mining," this volume documents the evaluation of the long-term stability of four head-of-hollow fills. Three phases of work included in the endeavor are:

- Collection of samples of valley fill material at several locations; determination of sample moisture content, density and shear strength; and application of these parameters to stability analysis,
- Analysis of water carrying capacity of rock chimney drains, and
- Evaluation of the reliability and effectiveness of remote data collection techniques.

Other segments of this EPA study are presented in a separate volume, including the environmental assessment of the effects of coal mining and reclamation techniques employed in Kentucky and West Virginia mountaintop removal and head-of-hollow fill construction.

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# FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-CI) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This study details the results of the subsurface investigations and stability analyses of four head-of-hollow fills. This subject has been under study by the Energy Pollution Control Division of the Industrial Environmental Research Laboratory which may be contacted for further information.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

# ABSTRACT

As a portion of the EPA study "Environmental Assessment of Head-of-Hollow Fill and Mountaintop Removal Mining," this volume documents the evaluation of the long-term stability of four head-of-hollow fills. Three phases of work included in the endeavor are:

- Collection of samples of valley fill material at several locations; determination of sample moisture content, density and shear strength; and application of these parameters to stability analysis.
- Analysis of water carrying capacity of rock chimney drains.
- Evaluation of the reliability and effectiveness of remote data collection techniques.

Other segments of this EPA study are presented in a separate volume, including the environmental assessment of the effects of coal mining and reclamation techniques employed in Kentucky and West Virginia mountaintop removal and head-of-hollow fill construction.

This report was submitted in partial fulfillment of Contract Number 68-03-2354 by Skelly and Loy under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period September 1979 to October 31, 1981.

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## ACKNOWLEDGEMENT

The cooperation of the mining companies which participated in this portion of the overall study is gratefully acknowledged.

# SECTION 1
# INTRODUCTION

The original scope of work for the study entitled "Environmental Assessment of Surface Mining Methods: Head-of-Hollow Fill and Mountaintop Removal" did not include an analysis of the long-term stability characteristics of various head-of-hollow and valley fill construction techniques. Subsequent modification of that original scope resulted in initiation of this study, which consisted of investigations to evaluate the adequacy of internal and external drainage structures, signs of slippage and instability, and the specific characteristics of the in-place fill material at four head-of-hollow or valley fill sites in Kentucky and/or West Virginia. This document presents the results of these analyses.

The sites selected for investigation were chosen primarily because of their age -- all are fairly old fills. It was hoped that this would give some insight into material consolidation with time. The West Virginia Surface Mining and Reclamation Association and the Department of Natural Resources assisted in the location of potential sites in West Virginia. In the state of Kentucky, previous experience and contacts with the state's mining industry were important in identifying appropriate sites.

Visual observation of the external conditions of the fills formed the first phase of the field investigations. Test borings were drilled to obtain samples of the fill material and to provide information for correlation with follow-up seismic and electrical resistivity geophysical investigations.

Several times throughout the course of the study period, the sites in West Virginia were visited to observe the rock core chimney drains and assess their performance. At no time was there a reliable measurable flow into the core drain at the head of the hollow at any site.

Unfortunately, mining company personnel were less cooperative with regard to our proposal to study procedures for constructing diversion ditches. Many people declined to participate in the study to avoid undue attention of regulatory officials.

# SECTION 2
# CONCLUSIONS

## SURFACE INSPECTION

During the summer months, dense growths of lespedeza and other grasses made it difficult to walk over the fill slopes and, in particular, to detect any surface defects. However, surface inspection in the fall was easier because the vegetation was entering dormancy. Small erosion channels which had been obscured by dense summer vegetation were clearly observable in the fall.

The effect of erosion at various locations on the long-term stability is difficult to predict. There is little doubt that it will result in the continued creation of steep slopes along the erosion channel which will collapse and add to the sediment load of streams below the fill. There is no way of predicting the occurrence of a massive slide in the future.

## SUBSURFACE INVESTIGATIONS

The drilling of standard test borings to obtain samples of head-of-hollow fill material proved satisfactory at the four sites investigated. Prior to initiation of this field work, it was thought that boulders would interfere with the sampling procedures. However, there was no significant difference in the rate of boring advancement using standard drive casing, hollow stem augers, or drilled-in casing. Newer fills, where less material weathering has occurred or where more numerous large boulders are present, would probably hamper the advancement of hollow stem augers.

Field sampling did prove that it was impossible to obtain undisturbed Shelby tube samples at any of the drilling locations because of the numerous rock fragments. Even a small rock particle can impede the advancement of this type of a sampler, which is pushed under hydraulic pressure.

## SEISMIC AND ELECTRICAL RESISTIVITY SURVEYS

The seismic refraction method was a most satisfactory geophysical method of supplementing the data obtained by test borings. The mobility of the seismic crew and its equipment made it possible to obtain subsurface rock profiles where the terrain made accessibility for a drill rig impossible.

From the field experience, it is clear that use of the seismic technique requires a skilled and knowledgeable interpreter because of the concave shaped contact between the fill and the bedrock. Another absolute requirement for this type of investigation is a multi-channel, full wave form recording seismograph in order to obtain reliable data.

Electrical resistivity methods did not prove satisfactory for a number of reasons. The length of the fill benches was too short to obtain penetration to define the entire depth of the fill. The drainage core trenches at the West Virginia sites also distorted the data, and resulted in negative resistivities.

## LABORATORY TESTS

The most significant problem encountered in the laboratory testing program was the size of the samples obtained. The number of large particles in some instances made it necessary to combine samples from more than one boring to generate sufficient material for remolding test specimens. Slight differences in the material types from boring to boring may have influenced strength test results.

In addition, the density data obtained using samples from split spoon samplers may be high because of the disturbance created by driving the sampler into the soil.

## SITE SPECIFIC RESULTS

The surface conditions of the West Virginia fills were generally good. The fill surfaces had excellent vegetation and showed little surface erosion. One of the fills had a significant wet zone on one of the benches, apparently the result of either poor grading or fill settlement causing ponding. At the second fill site, there was a major erosion scar in a drainage swale located on one of the fill abutments.

The valley fill sites in Kentucky are not as well vegetated as those investigated in West Virginia. Both of the fills examined had deep erosion gullies on the outslopes and near the fill abutments.

## SLOPE STABILITY

Both West Virginia fills have static factors of safety greater than 1.0 with and without seepage forces considered. The low factor of safety of 1.17 at West Virginia Site Sp is partially due to the steepness of the lower benches through which the critical circle passes. The two Kentucky valley fills also have stable slopes. Static factors of safety were greater than 1.5.

## ANALYSIS OF ROCK CHIMNEY DRAINS

The only comment that can be made relative to the rock chimney drains at the West Virginia fills is that they are functioning. Topographic conditions at the head of the hollow, backfilling of the highwall, and the location of the haulroads intercept the overland flow and prevent the water from reaching the drainage pockets on the fill platforms.

The Kentucky fills do not contain any special internal drainage such as the chimney drain in the West Virginia fills.

# SECTION 3
# RECOMMENDATIONS

It is difficult to draw conclusions relative to temporal change in the stability of the fills studied, since there was no base data collected at the time of construction which could have been compared with the results of this study. If the EPA considers this subject worthy of further investigation, a new fill should be studied during its construction to determine the strength of the spoil as it is placed.

An investigation of monitoring devices should be considered to determine their applicability to measuring the increase in fill strength with the passage of time. Items to be considered include slope indicators, settlement measuring equipment and pressure transducers. Research should be conducted to determine the feasibility of installing or using such devices as the Menard pressure meter or the Iowa bore hole shear device during construction to perform internal strength tests long after the end of construction.

In the future, if groundwater monitoring is to be a part of any investigations, more durable material than PVC plastic pipe should be used for casing the boreholes. Shortly after the standpipes were installed on this project they were vandalized and/or removed from some of the sites.

If a West Virginia style fill is constructed, more care can be exercised in assuring that surface drainage is directed to the rock chimney drain. Weirs then can be constructed at the channels into the drainage pocket and at the toe to measure the inflow and outflow.

# SECTION 4
# FIELD INVESTIGATION METHODS

Work on this project was initiated during the month of March, 1980 when potential participants were contacted. The object of the search was to locate fills which were in existence for a long period of time. Two of the fills chosen are in West Virginia and two are in Kentucky. Mining of all four sites was by the contour stripping method using valley fills to dispose of excess spoil. The fills in West Virginia were constructed concurrently during the years 1976 and 1977 by hauling the spoil down to the dumping point and spreading it. In Kentucky, the fills were also constructed in the years 1976 and 1977 and the spoil was merely pushed from the mine bench into the valley. The West Virginia fills are drained by central rock core drains whereas those in Kentucky have no obvious provisions for drainage.

## SURFACE INSPECTION

Surface inspection activities were initiated with surveys of the fills to develop plans and profiles showing their respective shapes. These efforts also served to pinpoint the locations of any notable or unusual features. A review of the physical conditions of each fill was made by walking over its outslope, along the benches where present, below the toe of the fill, and along the intersection of the fill and the existing natural ground. During this inspection, the presence of slumps, cracks, or any other signs indicative of slope failure were sought and noted. The locations of any seepage zones were also identified on the plans prepared from the surveys.

## SUBSURFACE INVESTIGATIONS

In anticipation of difficulties with the sampling of the subsoil at the valley fill sites, drilling contractors who were able to advance the boreholes by various methods were sought. This approach provided valuable data regarding drillability of valley fills. Drill holes were advanced using hollow stem augers, conventional drive casing and drilled in casing. Procedures for sampling of the soil and rock were the same for each contractor. The results of the drilling are contained in the Boring Logs, Appendix A. Geophysical methods, that is, seismic refraction and electrical resistivity were used to determine their applicability to investigating the subsurface of valley fills. The data from this phase of the investigations was used in conjunction with the information from the test borings to prepare profiles and cross sections of the subsurface at each site.

## Soil Sampling

Soil samples were obtained at each of the sites in accordance with the procedures and equipment prescribed by ASTM Designation D-1586. A split spoon sampler was used to perform Standard Penetration Tests (SPT) at vertical intervals of less than 1.52 m (5 ft), measured from the top of one sample to the top of the second sample. An SPT consists of driving a 5.1cm (2 inch) O.D. split barrel sampler into the soil using a 63.6 kg (140 pound) drop hammer falling freely for a distance of 0.76 m (30 inches). The number of blows required for each 15.2 cm (6 inches) of penetration in a test section was recorded on the boring log. The total number of blows required for the last 0.31 m (12 inches) is defined as the penetration resistance, N.

Samples obtained by this method were removed from the split spoon sampler and described as to their particle size, consistency, color and relative moisture content. Subsequently, portions of the samples were put into jars without force and were transported to the laboratory.

## Boring Advancement

Each of the three drilling contractors involved in the project used a different method of advancing the main stem of drill tools between sampling points.

At the two Kentucky sites, identified on the boring logs as B and Bu, the borings were advanced using "wireline" equipment. This method eliminates the need for driving the casing since it is advanced by drilling ahead using water. "Wireline" equipment makes it possible to change the drill bit at the leading edge of the tools without removing them from the soil or bedrock being drilled. Using this method it was possible to penetrate boulders without time consuming equipment changes and to obtain good samples.

At West Virginia site Sp the borings were advanced using hollow stem augers. The hollow stem auger consists of: 1) a section of seamless steel tube wrapped by a spiral auger flight equipped with a finger type auger head at the lower end; and 2) a center drill stem composed of drill rods to which are attached a center plug with a drag bit at the lower end and an adapter at the top. The adapter at the top of the drill stem is designed to permit advancement of the auger with the plug in place. As the hole is advanced additional lengths of hollow stem flights and center stem are added as required. The center stem and plug may be removed at any time during the drilling to permit disturbed and undisturbed soil sampling or core sampling below the bottom of the cutter head by utilizing the hollow stem flights as casing. Hollow stem augers cannot be used where a large number of boulders are encountered. A distinct advantage of the hollow stem augers is the fact that water is not needed to advance them. Thus they are useful in locating zones of seepage or groundwater in the soil.

The drilling contractor at West Virginia site SpS used conventional casing to keep the boreholes open. However, it was possible to drive it for only a short distance after which, it was equipped with a diamond tipped cutting shoe and was drilled into place. After reaming with the casing, it was necessary to clean the casing of rock fragments with a rotary drill bit. This task required additional time to perform. This method presented a problem when the water introduced for flushing the casing clean seeped away through the spaces among the boulders. The side friction between the boring walls and the drill steels made turning the drill stem difficult at times. This problem was overcome by slowly pouring a bio-degradable liquid detergent into the annular space between the casing and the boring wall.

Each of the methods described above performed the function of maintaining the bore holes open while executing penetration resistance tests. The wireline and standard drive casing generally can be used in most soil conditions, whereas the continuous flight augers are hampered by boulders.

The boring logs are contained in Appendix A and the analysis of the findings of this effort are discussed in the section of the report entitled Site Specific Data.

## Rock Sampling

Samples of the bedrock were obtained using diamond coring equipment. At sites B and Bu the core diameter was NQ, 0.048 m, (0.16 ft) and at Sp and SpS it was NX, 0.054 m, (0.18 ft).

## Groundwater Observations

As each boring was completed it was converted into a semi-permanent groundwater observation well by insertion of a slotted PVC pipe. The annular space between the observation pipe and the boring wall was filled with gravel except for the last two feet near the ground surface. This zone was filled with bentonite pellets or impervious native soil.

Groundwater observations consisted of measuring the distance to the free water surface from the ground surface at the end of each day as the drilling was underway. The loss of drill water and the presence of wet zones were also noted. Since the installation of the well points, readings have been taken on several occasions.

## Seismic Surveys

Seismic refraction surveys were conducted at the four sites to provide additional data on the thickness and configuration of the fills. This geophysical analysis method measures the compressional wave velocities of subsurface materials. The compressional wave velocity is a direct measure of the strength, hardness, and compaction of a material. Fill, for example has a low velocity (305 to 914 m/sec 1,000 to 3,000 ft/sec) while bedrock has a high velocity (1,828+ m/sec 6,000+ ft/sec). Groundwater typically shows a velocity of (1,524 m/sec 5,000 ft/sec). Since these subsurface velocities are consistent for specific material, it is possible to make measurements along the ground surface and interpret the nature of the subsurface materials present. In addition to identifying the materials present, it also is possible to interpret the subsurface structure, both the depths to various materials and profiles of the contacts between these materials.

The seismic investigation was conducted using a Dresser Industries RS-4, 12 channel, Refraction Seismograph, employing standard shallow seismic refraction techniques. The geophone spacing varied from 3m to 9m (10 to 30 ft). The source of seismic energy at each shot point was primacord detonated with an electric blasting cap. The seismic wave travel times were calculated from the photographic paper recording of the entire waveform at each geophone location. Additional shot point locations were used during this survey to provide maximum information on the configuration of the fill material.

## Electrical Resistivity Surveys

Electrical Resistivity surveys measure the change in the electrical resistivity of subsurface materials. The resistivity of a subsurface material is directly related to the amount and type of moisture present. Dry materials have a high resistivity, while wet materials, such as clay and weathered rock, have medium to low resistivity.

Resistivity soundings taken during this survey were intended to measure the vertical change in resistivity and to locate the depth to the groundwater table. A Soiltest R-40 Electrical Resistivity Meter recorded the resistivity data. Electrical soundings with Wenner electrode spacing were taken in an attempt to determine the depth of the groundwater table. With this method, four electrodes were spaced equally along the ground surface, a current was passed between the two outer electrodes, and the potential drop between the two inner electrodes was measured. After each measurement, the distance between electrodes was increased to observe the effect of deeper subsurface materials.

## SECTION 5
## LABORATORY TESTING METHODS

Laboratory tests of materials collected during the field activities previously discussed were conducted to determine pertinent physical properties of material constituting each of the valley fills investigated. Basic index properties such as grain size distribution, plasticity, in-place density, and moisture content were measured. Subsequent to the determination of these characteristics, samples were chosen for testing to evaluate strength parameters. However, the nature and quantity of material per sample limited the amount and the types of testing. Gradation curves and shear strength data are contained in Appendix B.

### VISUAL CLASSIFICATION

All samples received in the laboratory were classified visually following ASTM Designation D2488, which is a procedure for the identification and description of soils for engineering purposes based on visual examination and simple manual tests.

### WATER CONTENT

Water content tests, probably the simplest of all soil tests, were performed on all the samples. Water content, which is the ratio of the weight of water to the weight of dry solids in a sample, has a considerable influence on soil density and strength. The water content determinations were made in accordance with ASTM Designation D2488.

### ATTERBERG LIMITS

A limited number of samples were tested to determine their water content at the solid-plastic state and at the plastic-liquid state, that is, their Atterberg limits. The Atterberg limits are used in conjunction with natural water content data to evaluate the condition of the in-place soil. The liquid limit tests were performed in accordance with ASTM Designation D423 and plastic limit tests were performed following ASTM Designation D424.

## GRAIN SIZE DISTRIBUTION

The purpose of the grain size test is to determine the relative proportions of each grain size constituting a sample. The separation of the large size granular materials is accomplished by sieving. Hydrometer techniques are used to determine the percentages of silt and clay size particles. For this test a wet sieve analysis was used. The only samples which were degraded by this method were the shaley samples from the sites in Kentucky. The wet sieving and hydrometer procedures were performed in accordance with ASTM Designation D422.

## DENSITY TESTS

Due to the nature of the sampling techniques, the performance of this test was limited to selected samples. Generally, this test is limited to relatively undisturbed samples, such as those collected in thin wall Shelby tubes. However, the random occurrence of large rock fragments in the study's rock fills prevented sampling of the overburden with tube samplers.

The in situ density of intact samples was determined by first weighing the sample in air. The sample then was coated with a thin layer of wax and weighed while completely immersed in water. After this weighing procedure, the moisture content of the sample was determined. The dry density was calculated using the results of the various weighings.

## STRENGTH TESTS

Because of the nature of the samples obtained, the strength tests performed were limited to direct shear tests on remolded specimens. Since the material constituting the fill and the underlying soil had been disturbed, the test results are considered valid. Each direct test consisted of shearing three specimens under different normal loads to define the peak strength parameters of friction angle (o) and cohesion (c). The direct shear tests were performed in general accordance with ASTM Designation D3080.

## CLASSIFICATION PROCEDURE

All the soil samples tested in the laboratory were classified following ASTM D2487-69, "Classification of Soils for Engineering Purposes." It is based on laboratory determination of particle size characteristics, liquid limit and plasticity index. The first step in the procedure is to determine whether the material is coarse grained or fine grained. If more than 50 percent of the sample is retained on the No. 200 sieve, it is coarse grained; if less than 50 percent, it is fine grained. Group symbols and typical names for the materials they represent are as follows:

| GROUP SYMBOLS | TYPICAL NAMES | GROUP SYMBOLS | TYPICAL NAMES |
|---|---|---|---|
| GW | Well-graded gravels and gravel-sand mixtures, little or no fines | ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands |
| GP | Poorly graded gravels and gravel-sand mixtures, little or no fines | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays |
| GM | Silty gravels, gravel-sand-silt mixtures | OL | Organic silts and organic silty clays of low plasticity |
| GC | Clayey gravels, gravel-sand-clay mixtures | MH | Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts |
| SW | Well-graded sands and gravelly sands, little or no fines | CH | Inorganic clays of high plasticity, fat clays |
| SP | Poorly graded sands and gravelly sands, little or no fines | OH | Organic clays of medium to high plasticity |
| SM | Silty sands, sand-silt mixtures | PT | Peat, muck and other highly organic soils |
| SC | Clayey sands, sand-clay mixtures | | |

# SECTION 6
# SITE SPECIFIC RESULTS

## WEST VIRGINIA SITE SP

Site Sp is located approximately 40 km (25 mi) southeast of Charleston, West Virginia. This fill is situated in a narrow hollow, typical of southern West Virginia, where the relief is 160 m (525 ft). Figure 1 is a plan view sketch of the fill. Geometrically, the fill consists of four benches and a platform. The slope angle of the benches varies from 0.45 radians (25.8°) to 0.63 radians (36°). The vertical distance between benches varies from 5.79 m (19 ft) to 24.38 m (80 ft). The outslope is somewhat steeper than shown on the permit application drawings and the height between benches does not agree with the design profile.

The fill surface is well vegetated with lespedeza and there is a stand of conifers on Bench D. There is minor surface erosion on the fill surface; that is, scars less than 0.15 m (0.5 ft) deep and occuring only in non-vegetated areas. Figure 2 is a photograph revealing a notably wet area on Bench D (also shown in Figure 1). The former highwall is completely backfilled and grass covered except for one small area north of the fill platform. Photo B of Figure 2 shows a portion of this eroded area.

Three standard test borings, located in Figure 1, were drilled to provide data on the material comprising the fill and the underlying natural soil and bedrock. Two of the borings, Sp1 and Sp3, were drilled on the platform and Sp2 was drilled on the first bench below the platform. Seismic survey lines were positioned along the platform and all benches but the lowest. Resistivity soundings also were made at the same locations. The results of the test borings are presented on the boring logs (Figures A-1 through A-5, Appendix A). The subsurface profile, Figure 3, and the cross sections, Figure 4, show the results of the seismic survey. When the soil resistivity was computed from the field readings, it was negative for the deep soil zones. This anomaly in the data is attributed to the rock core chimney drain. If the benches were considerably longer it is probable that reliable data would have been obtained.

An analysis of the test boring logs and soil samples show the following for valley fill Sp.:

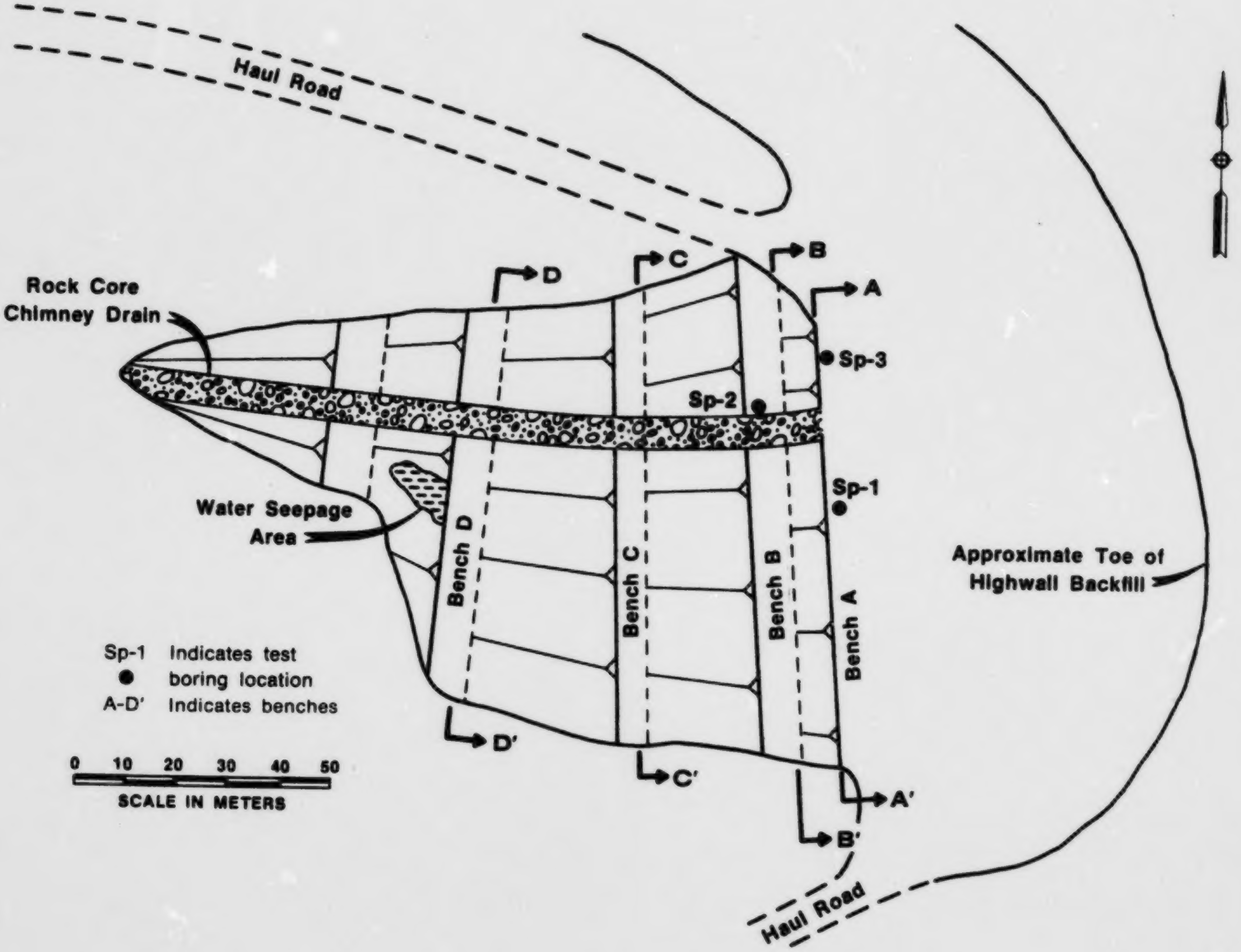
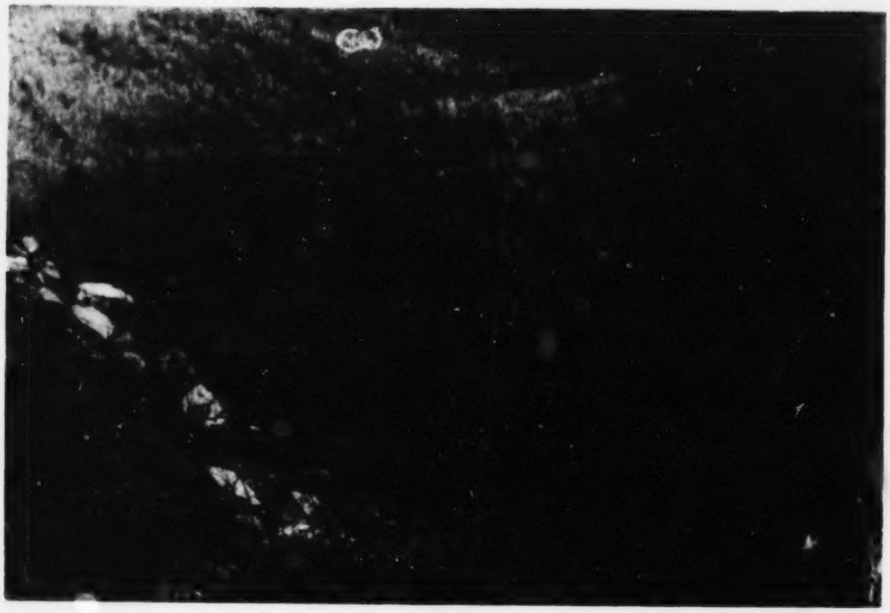
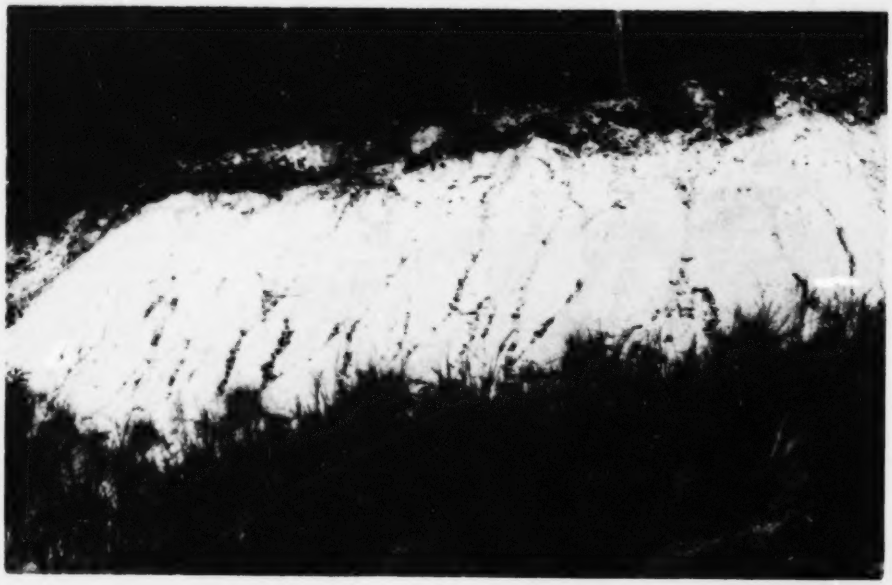

Haul Road
Rock Core
Chimney Drain
D
C
B
A
Sp-3
Sp-2
Sp-1
Water Seepage
Area
Bench D
Bench C
Bench B
Bench A
Approximate Toe of
Highwall Backfill
Sp-1 Indicates test
● boring location
A-D' Indicates benches
0 10 20 30 40 50
SCALE IN METERS
D'
C'
B'
A'
Haul Road

FIGURE 1. Valley fill site Sp - plan.



Water seepage area.



Erosion of natural soil above highwall.

FIGURE 2. Topographic conditions at site Sp.

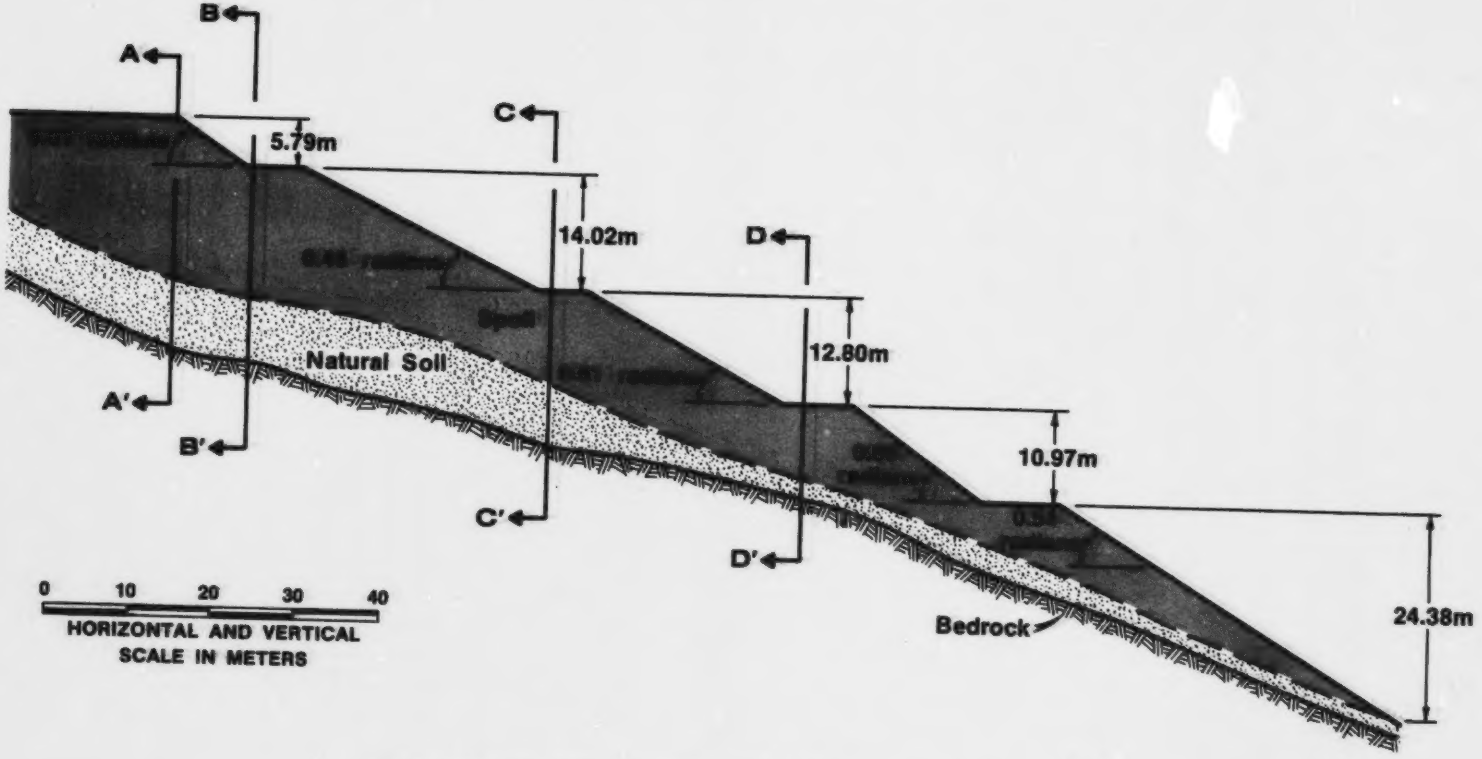
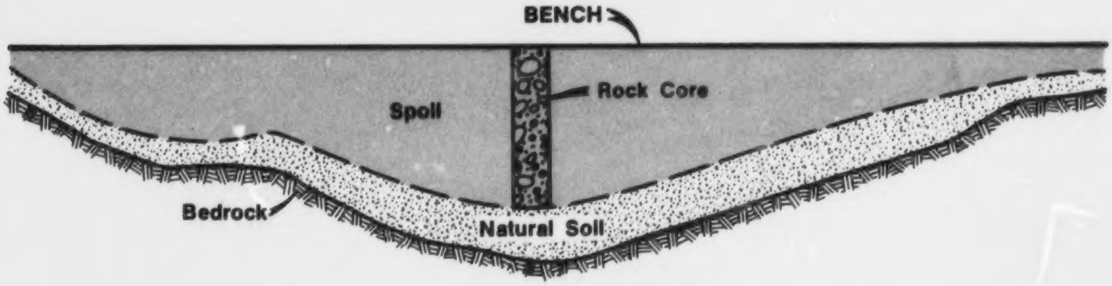
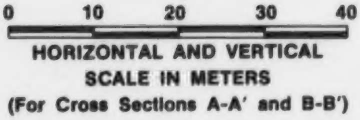
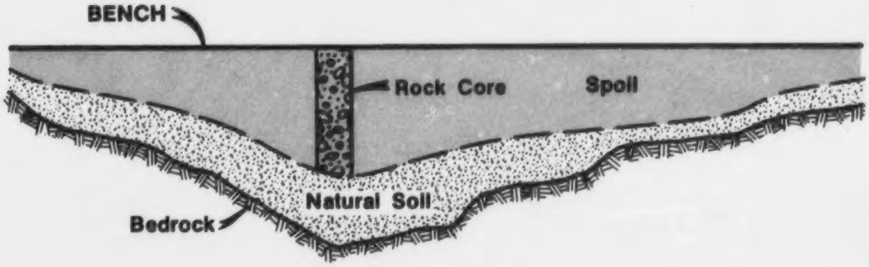

A
A'
B
B'
C
C'
D
D'
5.79m
14.02m
12.80m
10.97m
24.38m
Spoil
Natural Soil
Bedrock
0
10
20
30
40
HORIZONTAL AND VERTICAL
SCALE IN METERS

FIGURE 3. Valley fill site Sp - profile.

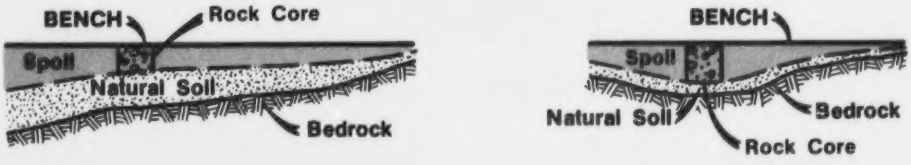

BENCH
Rock Core
Spoil
Bedrock
Natural Soil

CROSS-SECTION A-A′


0
10
20
30
40
HORIZONTAL AND VERTICAL
SCALE IN METERS
(For Cross Sections A-A′ and B-B′)


BENCH
Rock Core
Spoil
Natural Soil
Bedrock

CROSS-SECTION B-B′


BENCH
Rock Core
Spoil
Natural Soil
Bedrock
BENCH
Spoil
Natural Soil
Bedrock
Rock Core

CROSS-SECTION C-C′

CROSS-SECTION D-D′

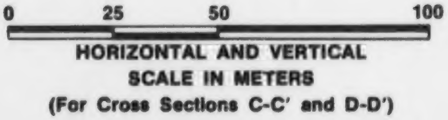

0
25
50
100
HORIZONTAL AND VERTICAL
SCALE IN METERS
(For Cross Sections C-C′ and D-D′)

**FIGURE 4. Valley fill site Sp - cross-sections.**

| Boring No. | Fill Thickness | Natural Soil Thickness |
|---|---|---|
| Sp1 | 18.29 m (60 ft) | 9.91 m (32.5 ft) |
| Sp2 | 15.24 m (50 ft) | 9.45 m (31.0 ft) |
| Sp3 | 12.19 m (40 ft) | 7.16 m (23.5 ft) |

The standard penetration resistance showed a distinct increase in each of the borings at the depths where the natural overburden was encountered. While making the visual classification of the samples it also was possible to distinguish the natural overburden soils from the overlying spoil. Laboratory tests classified the spoil primarily as gravel-sand-silt-clay mixtures and the natural soil is classified as a silty sand. Gradation curves of all the samples tested are shown in Figures B-1 through B-10, Appendix B.

In addition to classification tests, the in-place densities of seven samples were determined. The results of the density tests are as follows:

| Sample No. | Depth (m) | Moisture Content (%) | Dry Density (kg/m$^3$) | Degree of Saturation (%) |
|---|---|---|---|---|
| Sp1-1 | 0.0-0.46 | 12.5 | 1809 | 70.9 |
| Sp1-6 | 7.62-8.08 | 11.6 | 1812 | 66.1 |
| Sp2-7 | 9.14-9.60 | 18.2 | 1689 | 84.3 |
| Sp2-14 | 19.81-20.27 | 11.1 | 2049 | 99.5 |
| Sp2-17 | 24.38-24.69 | 13.1 | 2009 | 100.0 |
| Sp3-6 | 7.62-8.08 | 14.7 | 1603 | 59.3 |
| Sp3-11 | 15.24-15.70 | 8.7 | 1939 | 62.5 |

As indicated in the tabulation, only two samples (Sp2-14 and Sp2- 17) show complete or nearly complete saturation. This data correlates with the water table depth of 20.5 m (67.3 ft.) in boring No. Sp2 on October 21, 1980. According to the water level observations in Borings Sp1 and Sp3, all the other density samples were located above the water table.

The moisture density data were used as a guide for remolding samples of the spoil and natural soil for the determination of their shear strength by direct shear testing. The direct shear tests resulted in the following shear strengths:

| | Friction Angle | Cohesion |
|---|---|---|
| Fill Material | 0.36 rad (21°) | 1566 kg/m$^2$ (.16 T/SF) |
| Natural Overburden | 0.56 rad (32°) | 587 kg/m$^2$ (.06 T/SF) |

The direct shear test curves are shown as Figures B-39 and B-40, Appendix B.

As mentioned under the general discussion on field procedures, standpipes were installed in each of the borings to observe water level fluctuations over an extended period of time. During the course of drilling, seepage was noted in Boring Sp1 at depths of 6.1 m (20 ft.) and 12.19 m (40 ft.) and in Boring Sp2 at depths of 7.62 m (25 ft.) and 10.67 m (35 ft.). In both borings the seepage zones occur in the spoil. The following is a tabulation of readings taken when the borings were completed on October 21, 1980:

|  | Depth to Water |  |
|---|---|---|
| Boring No. | Upon Completion | 10/21/80 |
| Sp1 | 12.2 m (39.9 ft) | 20.5 m (67.3 ft) |
| Sp2 | Not recorded | 18.1 m (59.5 ft) |
| Sp3 | 15.4 m (50.5 ft) | 13.2 m (43.3 ft) |

The readings do not show any uniformity between the two observation dates. Instead of showing consistency in either falling or rising, the water level fell at one location and rose at the other. Future readings may prove to be more consistent. Comparing the water level readings of October 21, 1980 with the fill thickness, the water table is slightly below the top of the natural soil. For the stability analysis it was assumed that the phreatic surface follows the line of contact between the fill and the natural soil.

## WEST VIRGINIA SITE SpS

This site is located approximately 2.4 km (1.5 mi) north of previously discussed Site Sp. In fact, mining here was completed by the same firm and the same coal seam was mined.

Natural topographic conditions and the steepness of the valley fill slope limited the location of the test borings to the fill platform. Three test borings were drilled at the locations shown in Figure 5.

The fill benches and outslopes are covered by a dense growth of lespedeza and the natural slopes forming the abutments are covered with tall hardwood trees. There are no signs of slippage anywhere on the fill surface and the only noticeable wet area is on the platform near the drainage pocket at the uppermost end of the rock chimney drain. The most noticeable topographic defect is a severe erosion gully leading from the haul road along the east side of the fill down to the lowest bench of the valley fill. The gully must have been present during construction since a portion of the lowest bench leading from the gully to the main drain is lined with rock similar to that in the rock chimney drain. Presently there is a vertical slope along the edge of the haul road where the gully begins. The erosion gully is shown in the photo on Figure 6. Except for

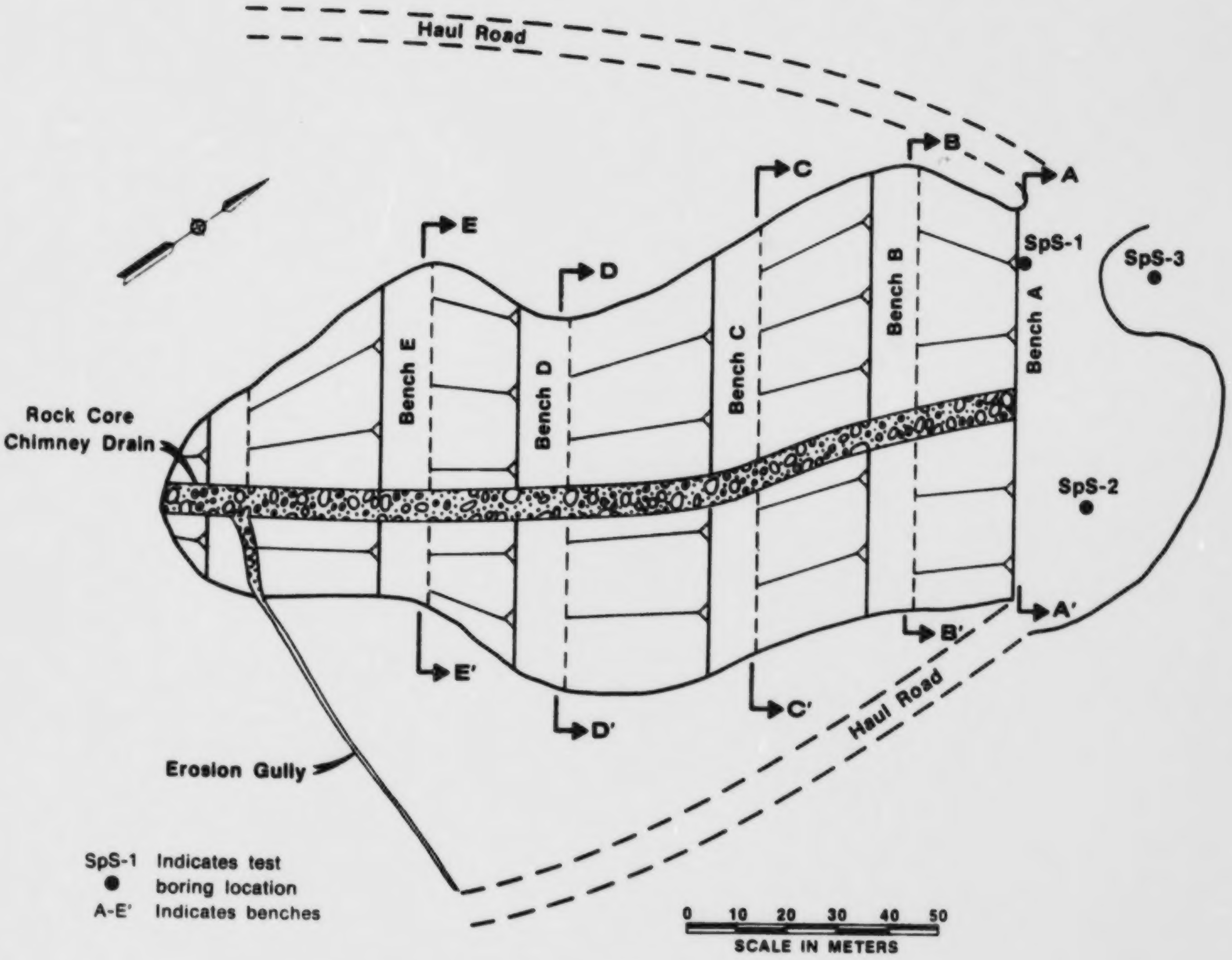

Haul Road
A
B
C
D
E
SpS-1
SpS-3
SpS-2
Bench A
Bench B
Bench C
Bench D
Bench E
Rock Core
Chimney Drain
A'
B'
C'
D'
E'
Haul Road
Erosion Gully
SpS-1 Indicates test
● boring location
A-E' Indicates benches
0 10 20 30 40 50
SCALE IN METERS

FIGURE 5. Valley fill site SpS - plan.

FIGURE 6. Erosion gully at site SpS.

the lowest bench which has a slope angle of 0.63 rad (36°), the slope angles are less than 0.45 rad (25.8°). The height between benches is 12.2 m (40 ft) or less, as shown on the profile, Figure 7. The zone between the backfilled highwall and the natural terrain above is more exposed than that at Site Sp, as illustrated by photos A and B in Figure 8.

The three standard test borings drilled at this site varied from 10.7 to 23.8 m (35.0 to 78.0 feet) in depth. Significant differences between Sites Sp and SpS are (1) the number of boulders encountered at Site SpS is greater and they are larger in size and (2) the natural overburden at Site SpS is considerably thinner, 2 m (6.5 ft) or less.

Seismic refraction surveys were performed at each bench except the lowest. The bedrock profiles determined are shown in Figures 7 and 9. No resistivity soundings were made because of the experience gained from the use of this method at Site Sp.

The large number of boulders at this site, most of which had to be diamond drilled to advance the borings to bedrock, limited the number of soil samples recovered from the penetration resistance tests. Due to the granularity of the spoil and its low moisture content, very few intact samples were recovered. As a result of this condition only three in situ density tests were performed, the results of which are:

| Sample No. | Depth (m) | Moisture Content (%) | Dry Density (kg/m$^3$) | Degree of Saturation (%) |
|---|---|---|---|---|
| SpS1-5 | 9.14-9.63 | 9.8 | 1961 | 73.4 |
| SpS2-3 | 3.05-3.20 | 12.8 | 1873 | 81.3 |
| SpS3-2 | 1.52-2.13 | 12.3 | 1905 | 82.8 |

The densities and moisture contents listed above are comparable to those determined from spoil samples from Site Sp.

The amount of material obtained was not adequate to remold a sufficient number of specimens to perform shear strength tests. However, considering the similarities in the topographic and geologic settings of Sites SpS and Sp, as well as the analagous in-place densities, the shear strength test results from Site Sp were used to analyze the stability of the fill at Site SpS.

The granular nature of the spoil at Site Sp is confirmed by the fact that six of eight gradation analyses resulted in the material classification of GM-GC or GM. The plasticity indices of all the samples tested are 8 or less and the natural moisture content is well below the plastic limit in each case. Thus the use of the shear strength test data from Site Sp, which were performed while completely saturated, is considered

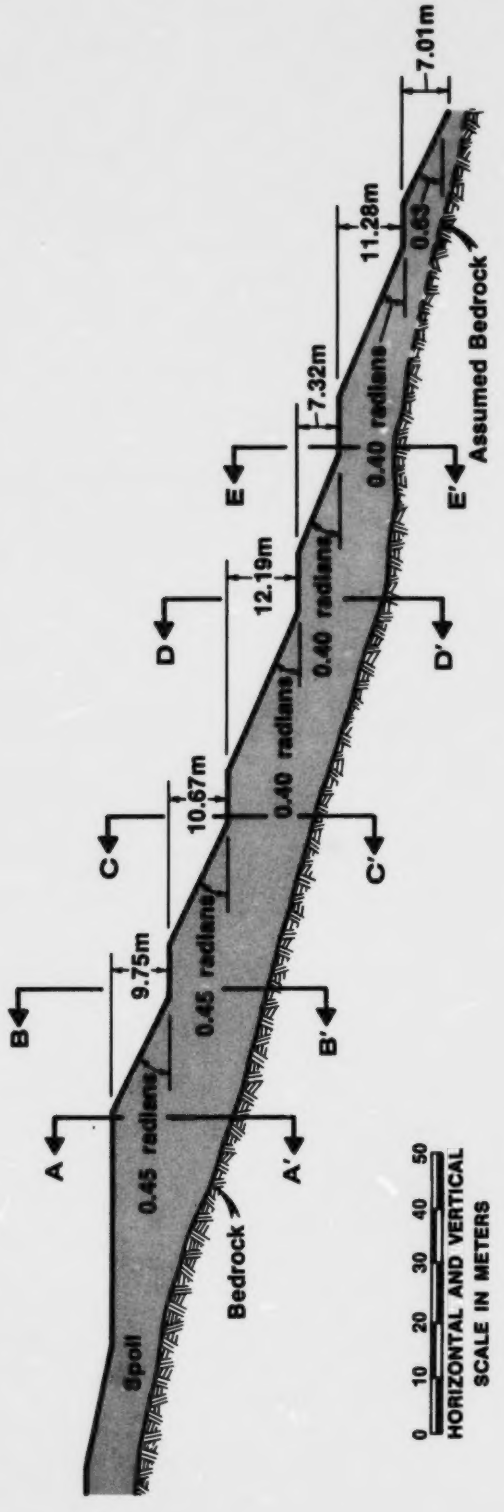
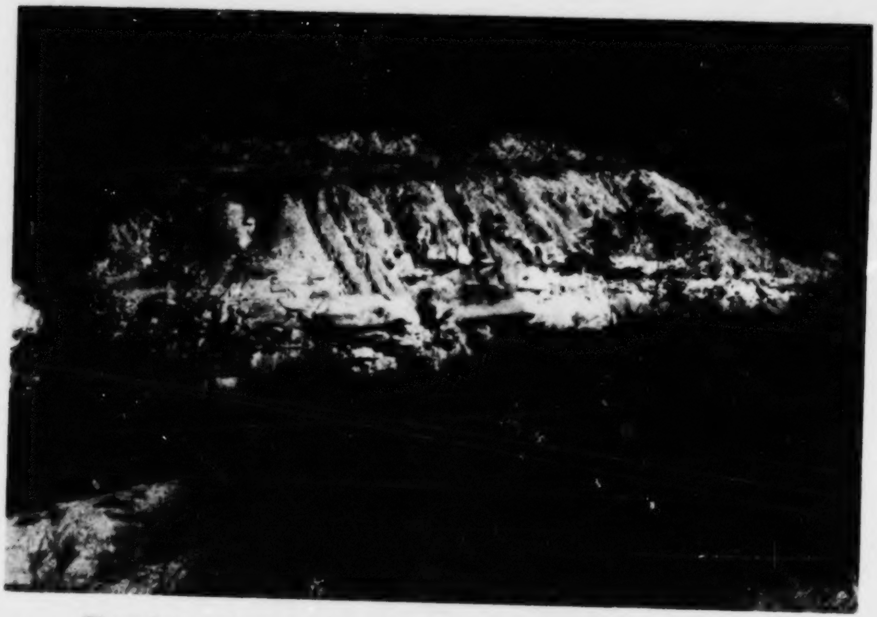

Spoil
Bedrock
Assumed Bedrock
A
A'
B
B'
C
C'
D
D'
E
E'
0.45 radians
0.45 radians
0.40 radians
0.40 radians
0.40 radians
0.40 radians
0.63
9.75m
10.67m
12.19m
7.32m
11.28m
7.01m
0 10 20 30 40 50
HORIZONTAL AND VERTICAL
SCALE IN METERS

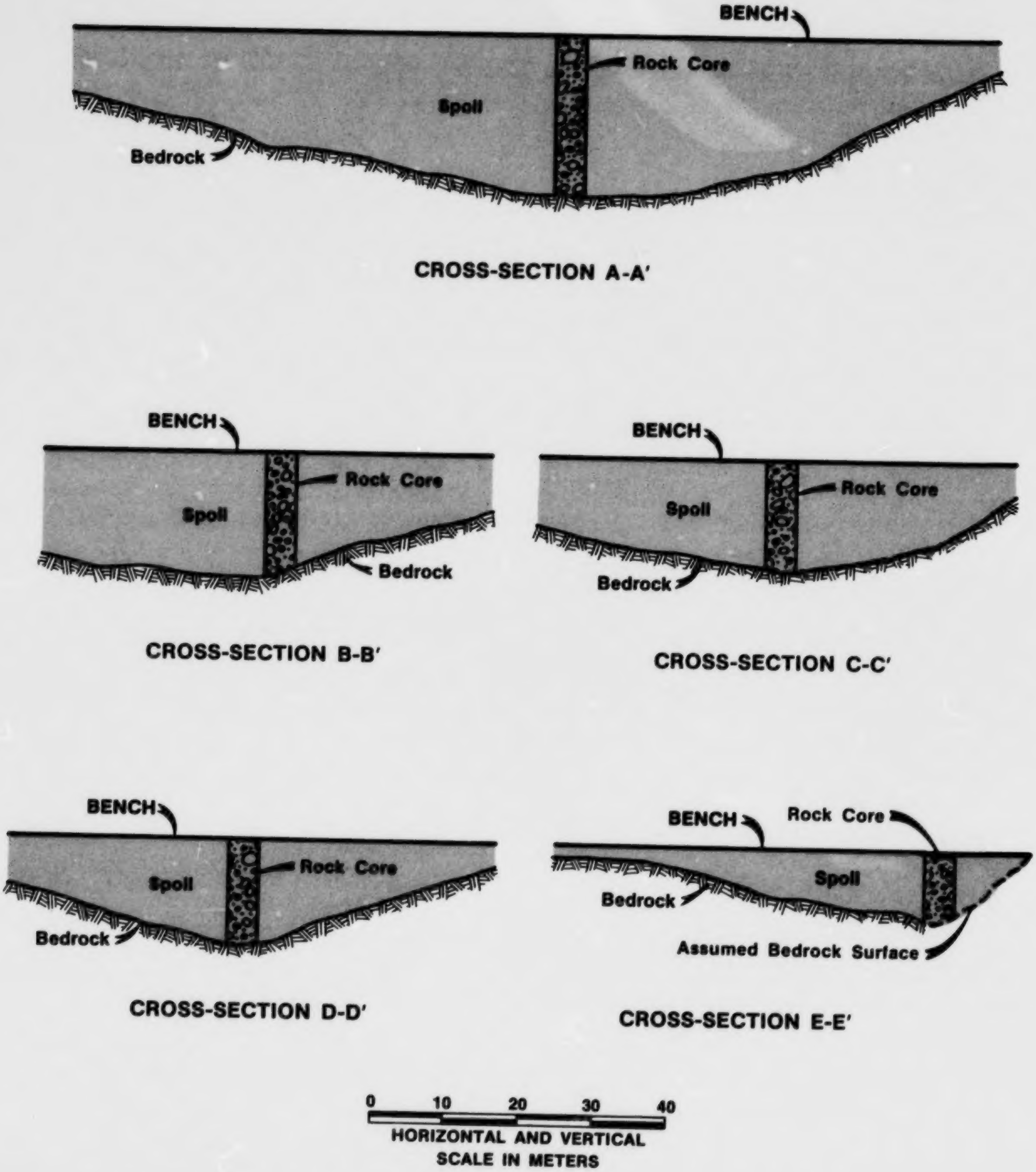
FIGURE 7. Valley fill site SpS - profile.

Barren slope above backfilled highwall.



Erosion of natural soil above backfilled highwall.

FIGURE 8. Topographic conditions at site SpS.


CROSS-SECTION A-A′

CROSS-SECTION B-B′

CROSS-SECTION C-C′

CROSS-SECTION D-D′

CROSS-SECTION E-E′

BENCH
Rock Core
Spoil
Bedrock
BENCH
Rock Core
Spoil
Bedrock
BENCH
Spoil
Rock Core
Bedrock
BENCH
Spoil
Rock Core
Bedrock
BENCH
Rock Core
Spoil
Bedrock
Assumed Bedrock Surface
0
10
20
30
40
HORIZONTAL AND VERTICAL
SCALE IN METERS

FIGURE 9. Valley fill site SpS - cross-sections.

conservative. The gradation curves are shown in Figures B-11 through B-18, Appendix B.

Groundwater observation wells also were installed at this site. At some time between a site visit in October and a subsequent visit in November, the standpipes in Borings SpS1 and SpS2 were damaged. The pipes were broken at the ground surface and it appears some soil or rock was dropped into the pipes. Thus, the validity of subsequent water readings is questionable.

The data obtained on the ground water are as follows:

| Boring No. | Depth to Water | | |
|---|---|---|---|
| | Upon Completion | 24 Hrs. After Completion | 10/22/80 |
| SpS1 | 18.9 m | 23.3 m | No Water |
| SpS2 | 9.4 m | 9.5 m | 12.2 m |
| SpS3 | 10.1 m | Not Recorded | 10.1 m |

The groundwater measurements show that the water level in each boring is below the bedrock surface and that there was a drop in the water levels between the time of completion and the measurements on October 21, 1980.

## KENTUCKY SITE B

This is the first of two valley fill sites in the eastern Kentucky coalfields included in this project. It is located approximately 16 km (10 mi.) northwest of the town of Hazard, Kentucky.

A sketch showing the general topographic features of the site is shown on Figure 10. The fill is part of a contour stripping operation and was constructed simply by pushing the spoil over the natural valley slope after clearing and grubbing. The slope was graded as necessary as additional fill was placed in order to comply with regulations in existence at the time of construction. No specific internal drainage system comparable to the West Virginia style rock core chimney drain was included in the fill.

Lespedeza covers the slope of the valley fill and the platform. There are no signs of sloughage within the area as shown in Figure 10. There is a severe erosion gully which traverses the face of the fill from the top of the slope down to the base of the hollow beyond the toe of the fill. The gully is the result of a large portion of the platform drainage being directed to the top edge of the slope. There is also a pond, situated to the rear of the platform, which may influence groundwater at the site. Photographs of the site are shown in Figure 11.

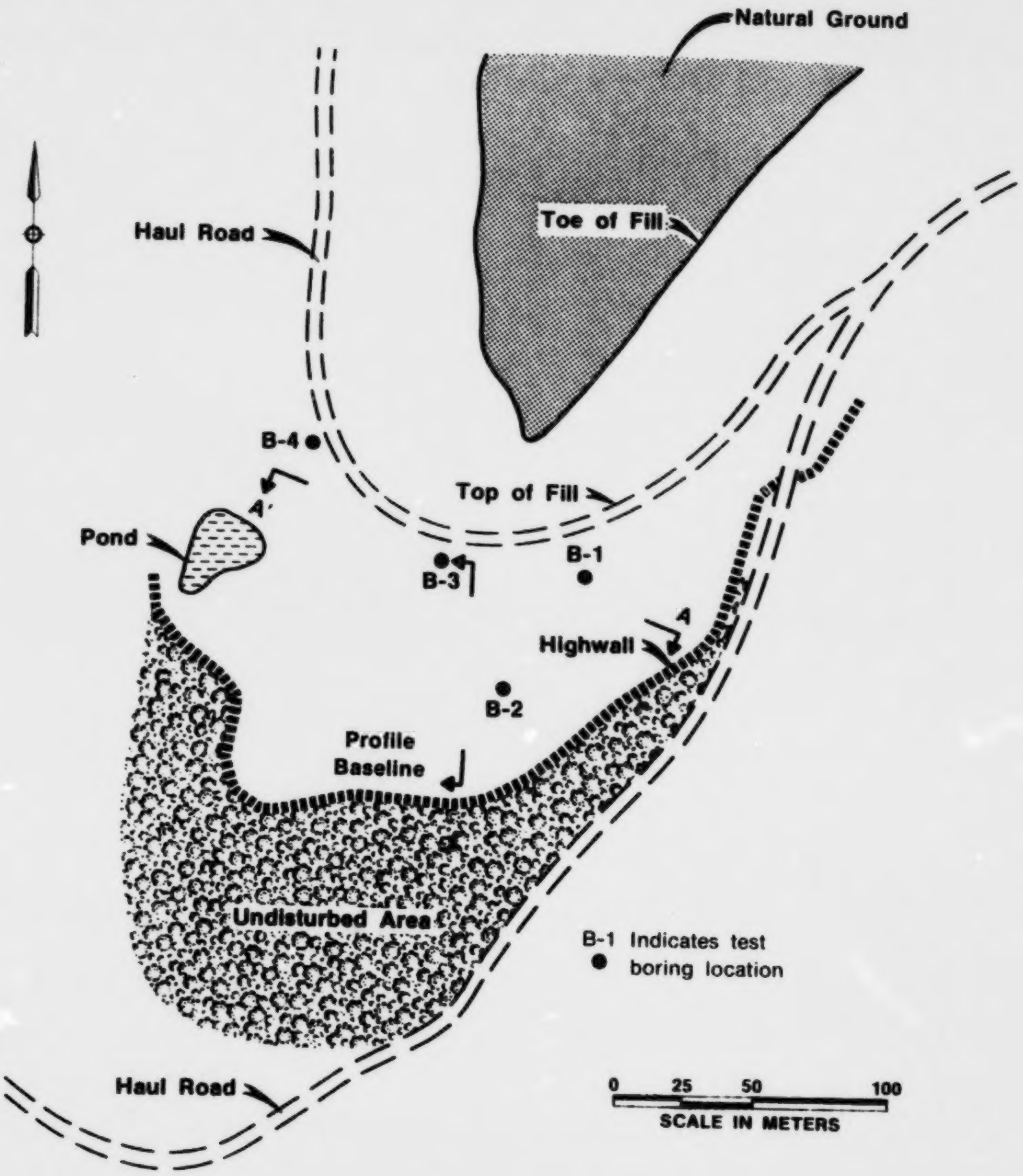

Natural Ground
Haul Road
Toe of Fill
B-4
A
Top of Fill
Pond
B-3
B-1
A
Highwall
B-2
Profile
Baseline
Undisturbed Area
B-1 Indicates test
● boring location
Haul Road
0
25
50
100
SCALE IN METERS

FIGURE 10. Valley fill site B - plan.

Overall view of valley fill.

Pond on valley fill platform.

FIGURE 11. Topographic conditions at site B.

The subsurface investigations conducted here consisted of four standard test borings, 2,683 m (8,801 ft) of seismic refraction survey line, and one electrical resistivity sounding. The boring locations are shown in Figure 10 and the subsurface profiles resulting from the seismic survey are shown in Figure 12.

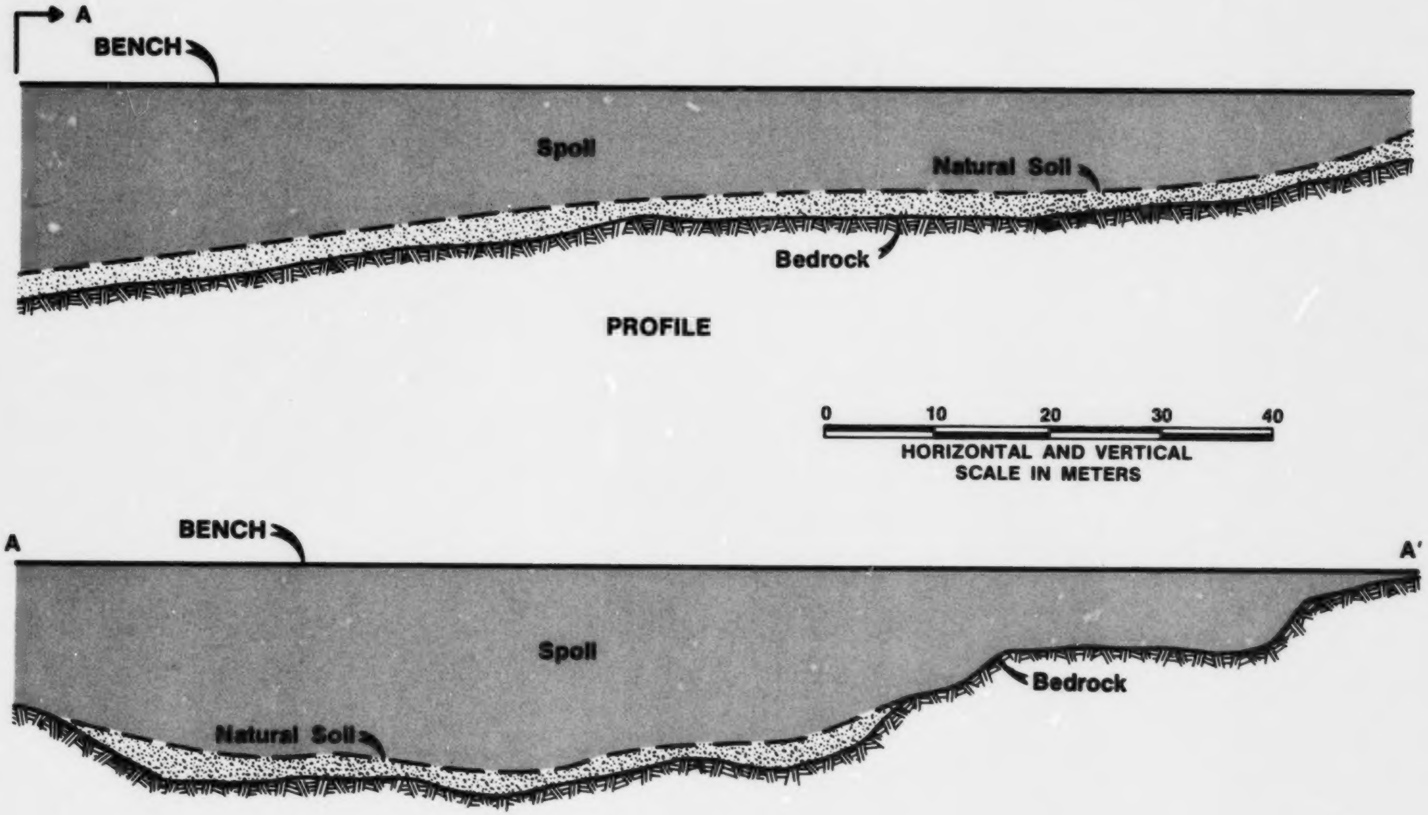
The depth to bedrock varied from 14.63 m (48.0 ft) to 24.26 m (79.6 ft). The depth of spoil material as determined by the borings is:

| Boring No. | Spoil Depth |
|---|---|
| B-1 | 14.94 m (49.0 ft) |
| B-2 | 8.38 m (27.5 ft) |
| B-3 | 22.40 m (73.5 ft) |
| B-3 | 11.86 m (38.9 ft) |

The classification of the soil varies from GM (silty gravels) down to CL (inorganic clays of medium plasticity). The penetration resistance values indicate that the fill is in a state varying from loose or soft to medium dense whereas the natural soil overburden is in a very dense state. The borings also reveal that there are not as many large boulders in the fill as were anticipated. The results of ten classification tests are shown in Figures B-19 through B-28, Appendix B.

Laboratory density tests performed on sixteen specimens resulted in the following data for subsequent use in shear strength tests and the evaluation of the fill stability:

| Sample No. | Depth (m) | Moisture Content (%) | Dry Density (kg/m3) | Degree of Saturation (%) |
|---|---|---|---|---|
| B2-1 | 0.0-0.46 | 16.7 | 1691 | 75.2 |
| B2-2 | 0.61-1.07 | 17.8 | 1861 | 100.0 |
| B2-11 | 11.73-12.19 | 13.6 | 1905 | 87.5 |
| B2-13a | 14.78-15.24 | 20.2 | 1715 | 94.4 |
| B2-13b | 14.78-15.24 | 20.2 | 1745 | 99.2 |
| B2-14 | 16.30-16.76 | 17.2 | 1810 | 93.9 |
| B3-1 | 0.0-0.46 | 10.1 | 1984 | 75.1 |
| B3-9 | 8.68-9.14 | 19.2 | 1762 | 96.9 |
| B3-11 | 11.73-12.19 | 15.6 | 1891 | 97.9 |
| B3-12a | 13.26-13.72 | 17.3 | 1777 | 89.5 |
| B3-12b | 13.26-13.72 | 17.3 | 1734 | 83.4 |
| B3-12c | 13.26-13.72 | 17.3 | 1726 | 82.4 |
| B4-1 | 0.61-1.07 | 13.5 | 1877 | 82.7 |
| B4-2 | 1.07-1.52 | 12.1 | 1981 | 89.4 |
| B4-3 | 2.59-3.05 | 15.6 | 1887 | 97.2 |
| B4-10 | 13.26-13.72 | 18.5 | 1834 | 100.0 |


A
BENCH
Spoil
Natural Soil
Bedrock
0
10
20
30
40
HORIZONTAL AND VERTICAL
SCALE IN METERS
A
BENCH
A'
Spoil
Bedrock
Natural Soil

PROFILE

CROSS-SECTION

FIGURE 12. Valley fill site B - profile and cross-section.

Sample B2-14 was chosen as representative of the natural ground and Sample B3-12 was selected as typical of the fill. Direct shear tests were performed on specimens remolded approximately to the densities for Samples B2-14 and B3-12 listed in the above tabulation. Graphs of the direct shear test results are shown in Figures B-41 and B-42.

Sample B2-14 had a friction angle of 0.63 rad (36°) and a cohesion of 1370 kg/m , and Sample B3-12 had a friction angle of 0.60 rad (34.5°) and a cohesion of 1566 kg/m .

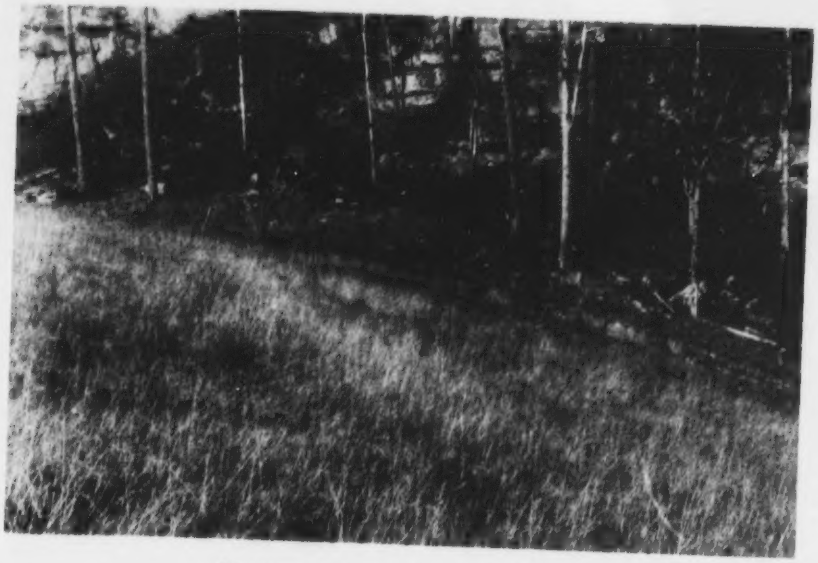
It appears that there may be a perched groundwater condition at this site. Water level observations made on three occasions after the completion of drilling showed the following:

| Boring No. | 9/25/80 | 10/2/80 | 11/21/80 |
|---|---|---|---|
| 1 | 7.28 m (23.9 ft) | 7.44 m (24.4 ft) | 7.80 m (25.6 ft) |
| 2 | 14.11 m (46.3 ft) | 14.39 m (47.2 ft) | 14.84 m (48.7 ft) |
| 3 | 13.29 m (43.6 ft) | 13.44 m (44.1 ft) | 15.12 m (49.6 ft) |
| 4 | 12.47 m (40.9 ft) | 12.56 m (41.2 ft) | 12.89 m (42.3 ft) |

A cased, large diameter groundwater observation well shows the average depth to the static water surface to be 46.3 m (152.0 ft) or more than 30.5 m (100 ft) below the top of the water surface as measured in the test borings.

## KENTUCKY SITE Bu.

Site Bu is situated on the Breathitt-Perry County line approximately 27.4 km (17 mi) northwest of Hazard, Kentucky. It is another contour mining site where valley fills were utilized for spoil disposal. The major difference between this site and Kentucky Site B is the length of the fill platform, which is approximately 610 m (2,000 ft). The platform is free of any large trees and the grass cover is sparse compared to that on the fill outslope. There are some small trees growing on the east abutment and a portion of the eastern slope of the fill. Older hardwood trees are growing on the west abutment. Photographs of the site are shown in Figure 13. No signs of slippage or instability are evident. However, the erosion which has taken place is severe. A gully measuring 2 m (6.6 ft) deep by 4 m (13.1 ft) wide has been eroded along the center of the fill. A second gully approximately 1.5 m (5 ft) deep and 1.5 m (5 ft) wide is situated near the intersection of the fill and the west abutment. Although the surface drainage has created these bare areas, there is no water flowing from the fill.



Valley fill west abutment.

Valley fill east abutment.

FIGURE 13. Topographic conditions at site Bu.

Although the platform is long, the test borings were drilled near the front face of the embankment as shown in Figure 14. The subsurface investigations consisted of four standard test borings, three resistivity soundings, and 536 m (1760 ft) of seismic refraction survey line.

The deepest boring Bu2 was drilled to 36.58 m (120 ft) and the shallowest Bu4 was drilled to 22.86 m (75 ft). Boring Bu4 was terminated when a tree was encountered between 21.49 m (70.5 ft) and 22.86 m (75 ft). Wood is particularly difficult to penetrate with either diamond bits or the saw tooth, carbide insert bits used for drilling rock. Thus, it was not possible to determine the complete underground profile in Boring Bu4. Subsurface profiles based on the seismic survey data and test borings are presented in Figure 15.

The classification test data show a wide range in particle sizes in the spoil. There are large rock fragments present (GM-GC) as well as silt and clay (CL-ML). The ocurrence of the various classes of material is random. The maximum fill thickness determined was 26.21 m (86.0 ft) in Boring Bu3 and the least amount of fill was found in Boring Bul, 13.56 m (44.5 ft). The in-situ density of the fill varies as randomly as its material classification according to the penetration resistance tests. There were a few areas where the blow count was four blows per foot or less, which indicates a soft or loose material. Generally, the fill can be considered as medium dense.

The natural soil which ranges in thickness from 1.83 m (6.0 ft) to 7.32 m (24.0 ft) had a somewhat higher penetration resistance than the spoil. The in-place densities determined on a number of samples at this site are listed in the following tabulation:

| Sample No. | Depth (m) | Moisture Content (%) | Dry Density (Kg/m$^3$) | Degree of Saturation (%) |
|---|---|---|---|---|
| Bul-1 | 0.0 - 0.46 | 17.9 | 1,886 | 100.0 |
| Bul-10 | 13.56-14.02 | 12.6 | 1,999 | 96.3 |
| Bu2-3 | 2.59- 3.05 | 15.8 | 1,827 | 88.8 |
| Bu2-5 | 5.64- 6.10 | 15.8 | 1,815 | 87.1 |
| Bu2-17 | 26.97-27.43 | 21.5 | 1,654 | 91.4 |
| Bu2-18 | 28.50-28.96 | 21.6 | 1,586 | 82.7 |
| Bu2-20 | 31.55-32.00 | 14.3 | 1,898 | 90.9 |
| Bu3-13 | 20.88-21.34 | 11.3 | 1,982 | 83.7 |

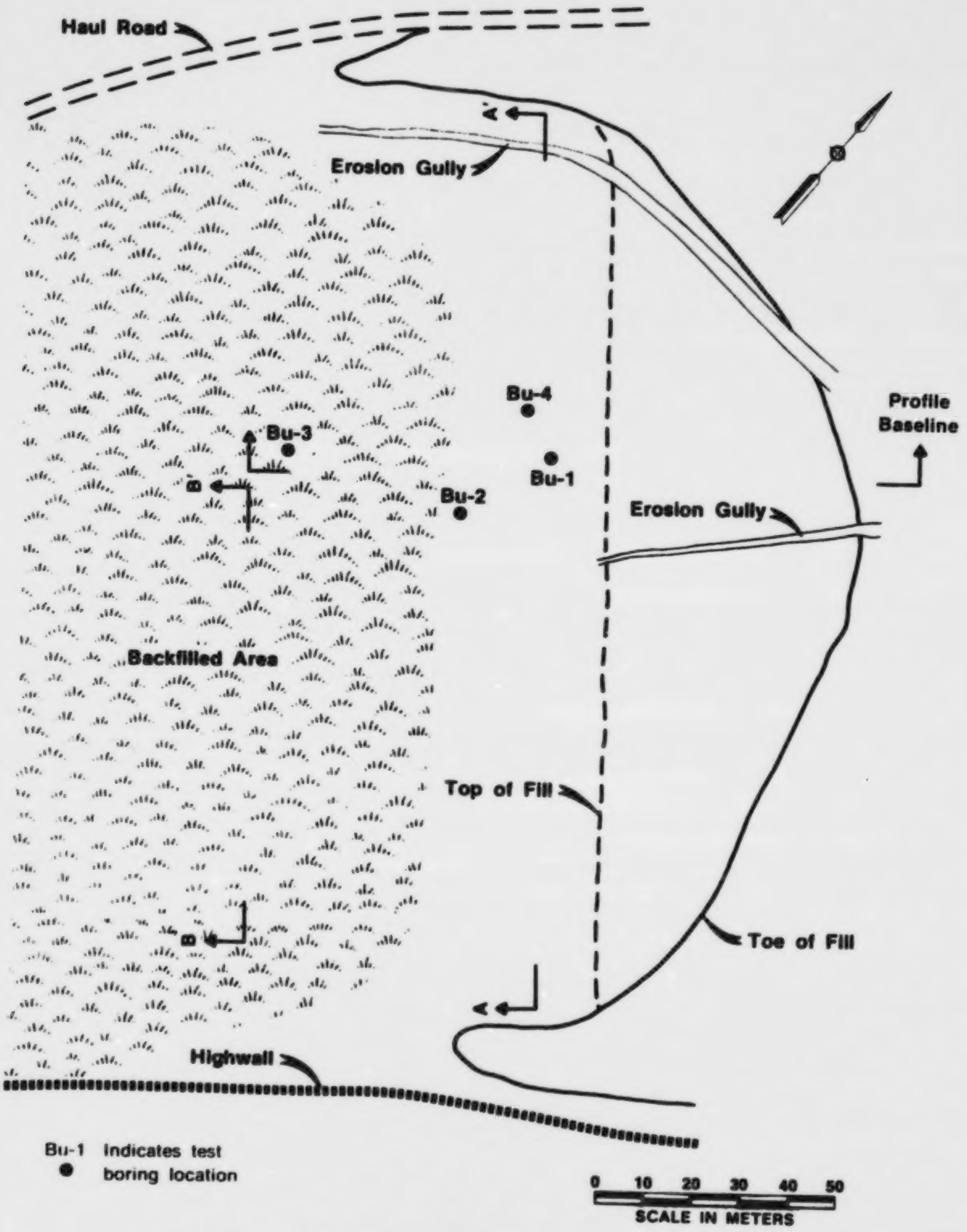
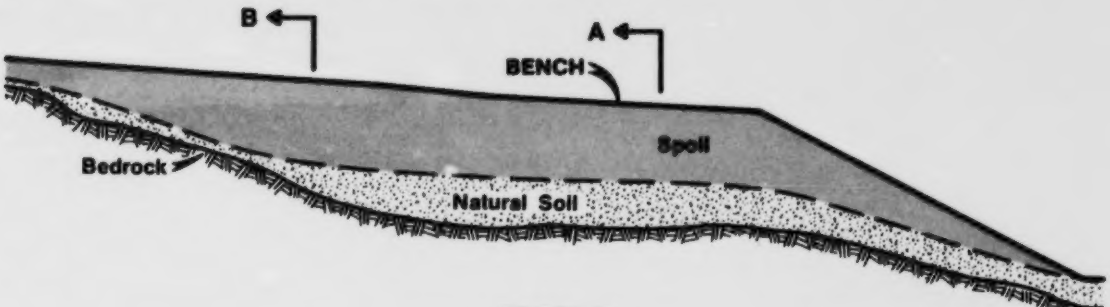
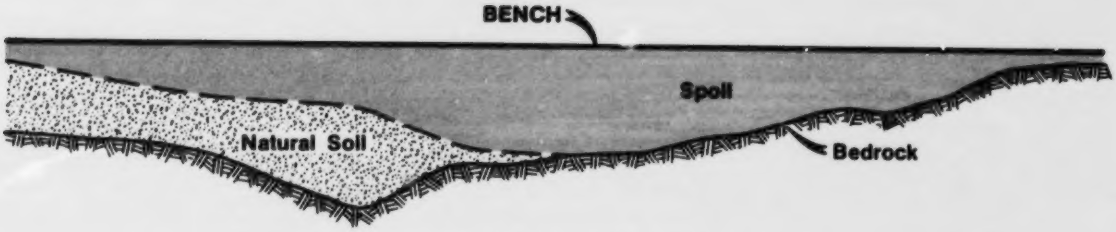

Haul Road
A'
Erosion Gully
Bu-4
Profile Baseline
Bu-3
B'
Bu-1
Bu-2
Erosion Gully
Backfilled Area
Top of Fill
B
Toe of Fill
A
Highwall
Bu-1 Indicates test
● boring location
0 10 20 30 40 50
SCALE IN METERS

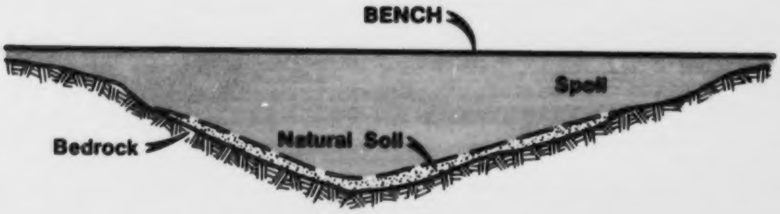
FIGURE 14. Valley fill site Bu - plan.


B
A
BENCH
Spoil
Bedrock
Natural Soil

PROFILE


BENCH
Spoil
Natural Soil
Bedrock

CROSS-SECTION A-A′


BENCH
Spoil
Bedrock
Natural Soil

CROSS-SECTION B-B′

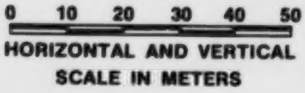

0
10
20
30
40
50
HORIZONTAL AND VERTICAL
SCALE IN METERS

FIGURE 15. Valley fill site Bu - profile and cross-sections.

| Sample No. | Depth (m) | Moisture Content (%) | Dry Density (Kg/m3) | Degree of Saturation (%) |
|---|---|---|---|---|
| Bu3-17 | 26.97-27.43 | 16.2 | 1,857 | 95.9 |
| Bu4-5 | 5.64- 6.10 | 18.5 | 1,778 | 95.9 |
| Bu4-8 | 10.21-10.67 | 18.1 | 1,704 | 83.2 |
| Bu4-8 | 11.73-13.72 | 16.5 | 1,852 | 96.7 |
| Bu4-14 | 20.88-21.34 | 15.5 | 1,865 | 93.0 |

The laboratory direct shear tests resulted in the following strength measurements for this site:

|  | Friction Angle | Cohesion |
|---|---|---|
| Fill Material | 0.48 rad. (27.5°) | 1,859 kg/m$^2$ (.19 tsf) |
| Natural Overburden | 0.68 rad. (39°) | 1,566 k/m$^2$ (.16 tsf) |

Graphs and data relative to the direct shear tests are contained in Figures B-43 and B-44, Appendix B.

Of the four sites investigated, Site Bu had the least amount of data available on groundwater. During the time period from the completion of drilling on August 9, 1980 to September 25, 1980, two of the groundwater wells were vandalized. On September 12, the depth to water was 23.09 m (75.7 ft) in Boring No. 1 and 27.16 m (89.10 ft) in Boring No. 2. The standpipes in test Borings 1 and 2 were damaged sometime after September 25, 1980 and before the day of another site visit October 2, 1980.

# SECTION 7
# SLOPE STABILITY ANALYSIS

The stability analysis of the valley fill slopes was performed using a computer program designated by the code name REAMES (Rotational, Equilibrium Analysis of Multilayered Embankments). It is a program authored by Dr. Yang H. Huang, of the Department of Civil Engineering, University of Kentucky, Lexington, Kentucky. In this program the Simplified Bishop method is employed. It is a widely used and accepted method of slices.

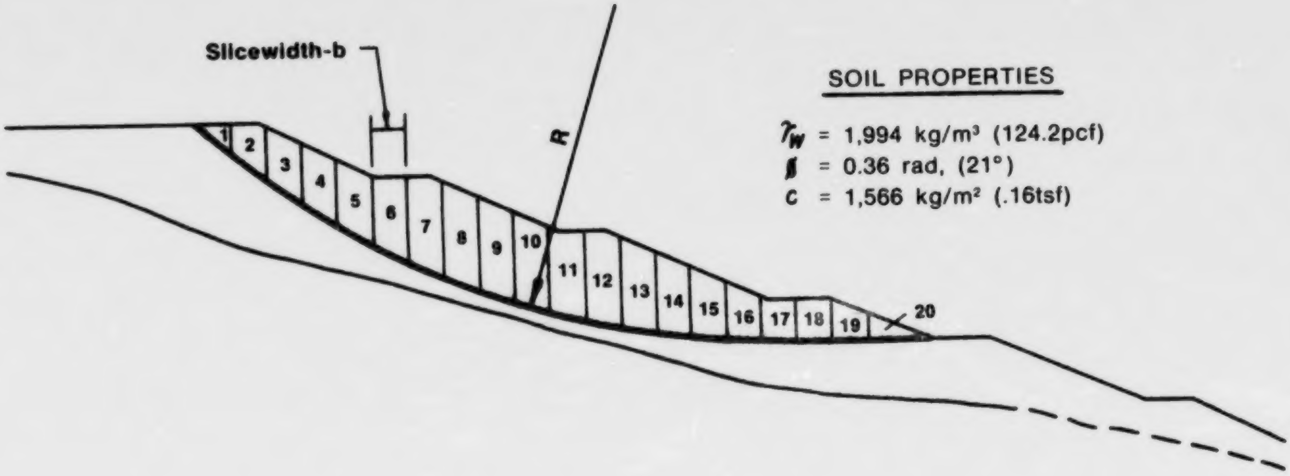
Each of the valley fill profiles was placed on a coordinate system and the data for the geometric cross-section were entered into a computer. Soil weight and strength parameters resulting from the laboratory tests were also entered into the program. A piezometric line was also assumed for each section based on the groundwater readings. An example of the calculation of the factor of safety is shown on Figure 16. The equation for F.S. is as follows:

$$\text{F.S.} = \frac{\Sigma\ [cbR + (Wt - ub)\ R \tan \emptyset]}{\Sigma\ Wt\ R \sin \alpha}\ \frac{1}{m_\alpha}$$

$$m_\alpha = \cos \alpha\ \left(1 + \frac{\tan \alpha \tan \emptyset}{\text{F.S.}}\right)$$

c = cohesion of soil (kg/m$^2$ or tsf)
b = width of slice (m or ft)
R = radius of ore of failure surface (m or ft)
Wt = weight of slice (kg or tons)
U = pore pressure (kg/m$^2$ or tsf)
O = friction angle of soil (rad or deg)
= angle of inclination of bottom of slice with a horizontal plane
F.S. = Factor of Safety

The program contains a search routine whereby it is possible to study a large number of centers in a short period of time. The grid patterns used for sites Sp, SpS, and Bu are shown in Figures 16, 17 and



SOIL PROPERTIES

$\gamma_W$ = 1,994 kg/m³ (124.2pcf)

$\phi$ = 0.36 rad, (21°)

c = 1,566 kg/m² (.16tsf)

| Slice No. | (1) Wt. (kips) | (2) b (ft.) | (3) α (deg.) | (4) c (kips/ft.) | (5) ø (deg.) | (6) u (ksf) | (7) cb (kips) | (8) ub (kips) | (9) Wt. sinα (kips) | (10) Wt.-ub (kips) | (11) Wt. tan ø (kips) | (12) (7)+(11) (kips) | (13) Mα | (14) (12)/(13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22.4 | 20 | 39 | .32 | 21 | 0 | 6.4 | 0 | 14.1 | 22.4 | 8.6 | 15.0 | .938 | 15.99 |
| 2 | 66.1 | 20 | 38 | .32 | 21 | 0 | 6.4 | 0 | 40.7 | 66.1 | 25.4 | 31.8 | .945 | 33.65 |
| 3 | 66.1 | 20 | 34 | .32 | 21 | 0 | 6.4 | 0 | 37.0 | 66.1 | 25.4 | 31.8 | .972 | 32.71 |
| 4 | 66.1 | 20 | 32 | .32 | 21 | 0 | 6.4 | 0 | 35.0 | 66.1 | 25.4 | 31.8 | .984 | 32.32 |
| 5 | 66.1 | 20 | 26 | .32 | 21 | 0 | 6.4 | 0 | 29.0 | 66.1 | 25.4 | 31.8 | 1.011 | 31.45 |
| 6 | 106.1 | 20 | 22.5 | .32 | 21 | 0 | 6.4 | 0 | 40.6 | 106.1 | 40.7 | 47.1 | 1.022 | 46.09 |
| 7 | 130.4 | 20 | 24 | .32 | 21 | 0 | 6.4 | 0 | 53.0 | 130.4 | 50.1 | 56.5 | 1.018 | 55.50 |
| 8 | 130.4 | 20 | 21.5 | .32 | 21 | 0 | 6.4 | 0 | 47.8 | 130.4 | 50.1 | 56.5 | 1.024 | 55.17 |
| 9 | 130.4 | 20 | 15 | .32 | 21 | 0 | 6.4 | 0 | 33.8 | 130.4 | 50.1 | 56.5 | 1.032 | 54.74 |
| 10 | 122.2 | 20 | 16 | .32 | 21 | 0 | 6.4 | 0 | 33.7 | 122.2 | 46.9 | 57.7 | 1.032 | 51.64 |
| 11 | 120.7 | 20 | 14 | .32 | 21 | 0 | 6.4 | 0 | 29.2 | 120.7 | 46.3 | 52.7 | 1.032 | 51.07 |
| 12 | 130.4 | 20 | 10.5 | .32 | 21 | 0 | 6.4 | 0 | 23.8 | 130.4 | 50.1 | 56.5 | 1.030 | 54.85 |
| 13 | 118.2 | 20 | 10.5 | .32 | 21 | 0 | 6.4 | 0 | 21.5 | 118.2 | 45.4 | 51.8 | 1.030 | 50.29 |
| 14 | 101.8 | 20 | 4.5 | .32 | 21 | 0 | 6.4 | 0 | 8.0 | 101.8 | 39.1 | 45.4 | 1.017 | 44.73 |
| 15 | 85.4 | 20 | 5 | .32 | 21 | 0 | 6.4 | 0 | 7.4 | 85.4 | 32.8 | 39.2 | 1.018 | 38.51 |
| 16 | 69.3 | 20 | 2 | .32 | 21 | 0 | 6.4 | 0 | 2.4 | 69.3 | 26.6 | 33.0 | 1.008 | 32.73 |
| 17 | 57.1 | 20 | 2.5 | .32 | 21 | 0 | 6.4 | 0 | 2.5 | 57.1 | 21.9 | 28.3 | 1.010 | 28.02 |
| 18 | 57.1 | 20 | .25 | .32 | 21 | 0 | 6.4 | 0 | -0.25 | 57.1 | 21.9 | 28.3 | -.999 | -28.33 |
| 19 | 40.7 | 20 | .5 | .32 | 21 | 0 | 6.4 | 0 | -0.36 | 40.7 | 15.6 | 22.0 | -.998 | -22.04 |
| 20 | 16.1 | 20 | 2 | .32 | 21 | 0 | 6.4 | 0 | -0.56 | 16.1 | 6.2 | 12.6 | -.990 | -34.07 |

Driving Forces = Σ9 = 458.33

Resisting Forces = Σ14 = 625.02

$$\text{F.S. } \frac{625.02}{458.33} = 1.36$$

Assumed initial F.S. = 1.5

**FIGURE 16. Cross section of valley fill site SpS and sample calculation of F.S. by simplified Bishop method of analysis.**

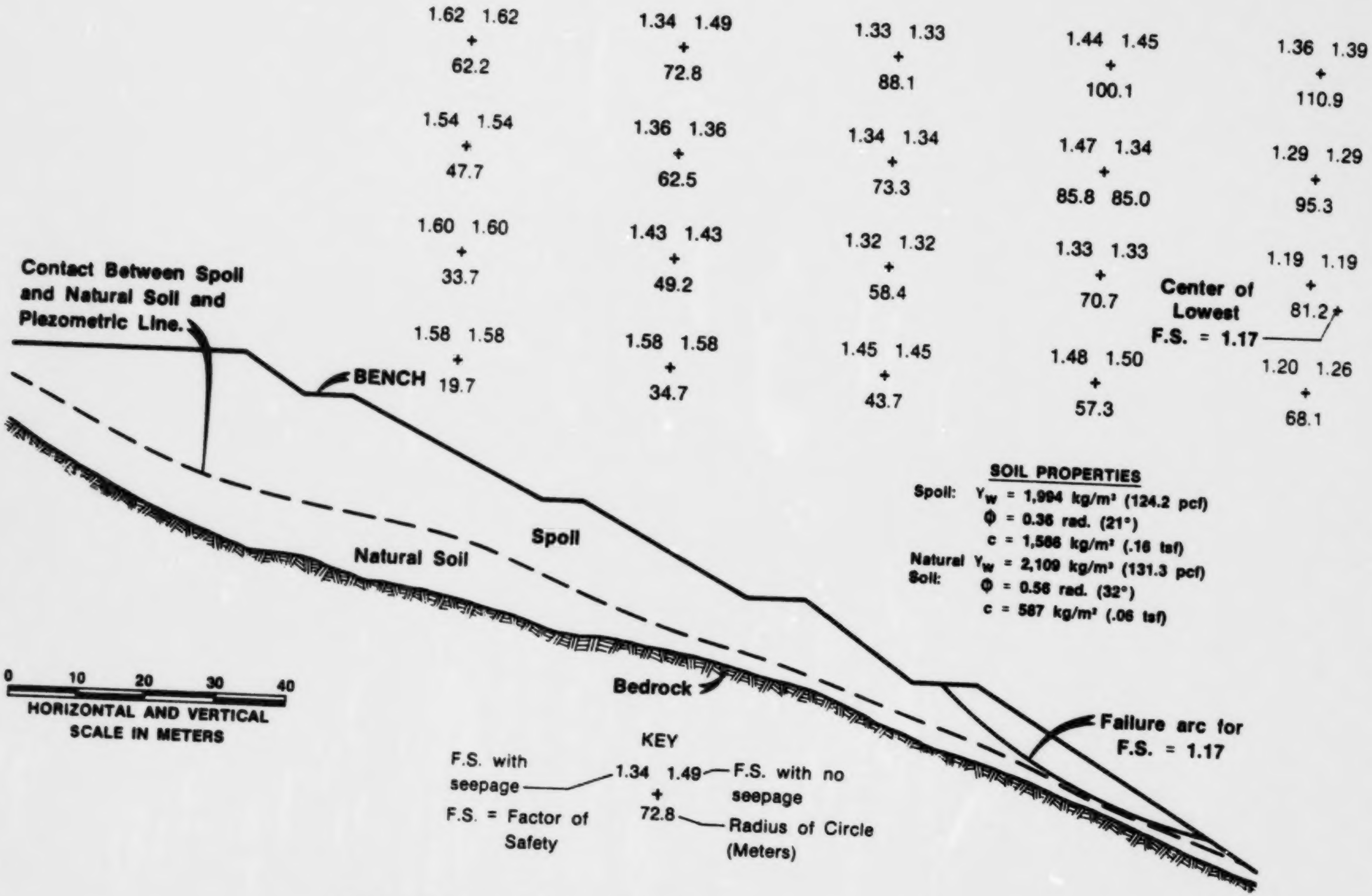

1.62 1.62
+
62.2
1.34 1.49
+
72.8
1.33 1.33
+
88.1
1.44 1.45
+
100.1
1.36 1.39
+
110.9
1.54 1.54
+
47.7
1.36 1.36
+
62.5
1.34 1.34
+
73.3
1.47 1.34
+
85.8 85.0
1.29 1.29
+
95.3
1.60 1.60
+
33.7
1.43 1.43
+
49.2
1.32 1.32
+
58.4
1.33 1.33
+
70.7
1.19 1.19
+
81.2
Center of Lowest F.S. = 1.17
1.58 1.58
+
19.7
1.58 1.58
+
34.7
1.45 1.45
+
43.7
1.48 1.50
+
57.3
1.20 1.26
+
68.1
Contact Between Spoil and Natural Soil and Piezometric Line.
BENCH
Spoil
Natural Soil
Bedrock
Failure arc for F.S. = 1.17
SOIL PROPERTIES
Spoil: $\gamma_w$ = 1,994 kg/m³ (124.2 pcf)
Φ = 0.36 rad. (21°)
c = 1,586 kg/m³ (.16 tsf)
Natural Soil: $\gamma_w$ = 2,109 kg/m³ (131.3 pcf)
Φ = 0.56 rad. (32°)
c = 587 kg/m³ (.06 tsf)
0
10
20
30
40
HORIZONTAL AND VERTICAL SCALE IN METERS
KEY
F.S. with seepage
1.34 1.49
+
72.8
F.S. with no seepage
Radius of Circle (Meters)
F.S. = Factor of Safety

FIGURE 17. Slope stability analysis - site Sp.

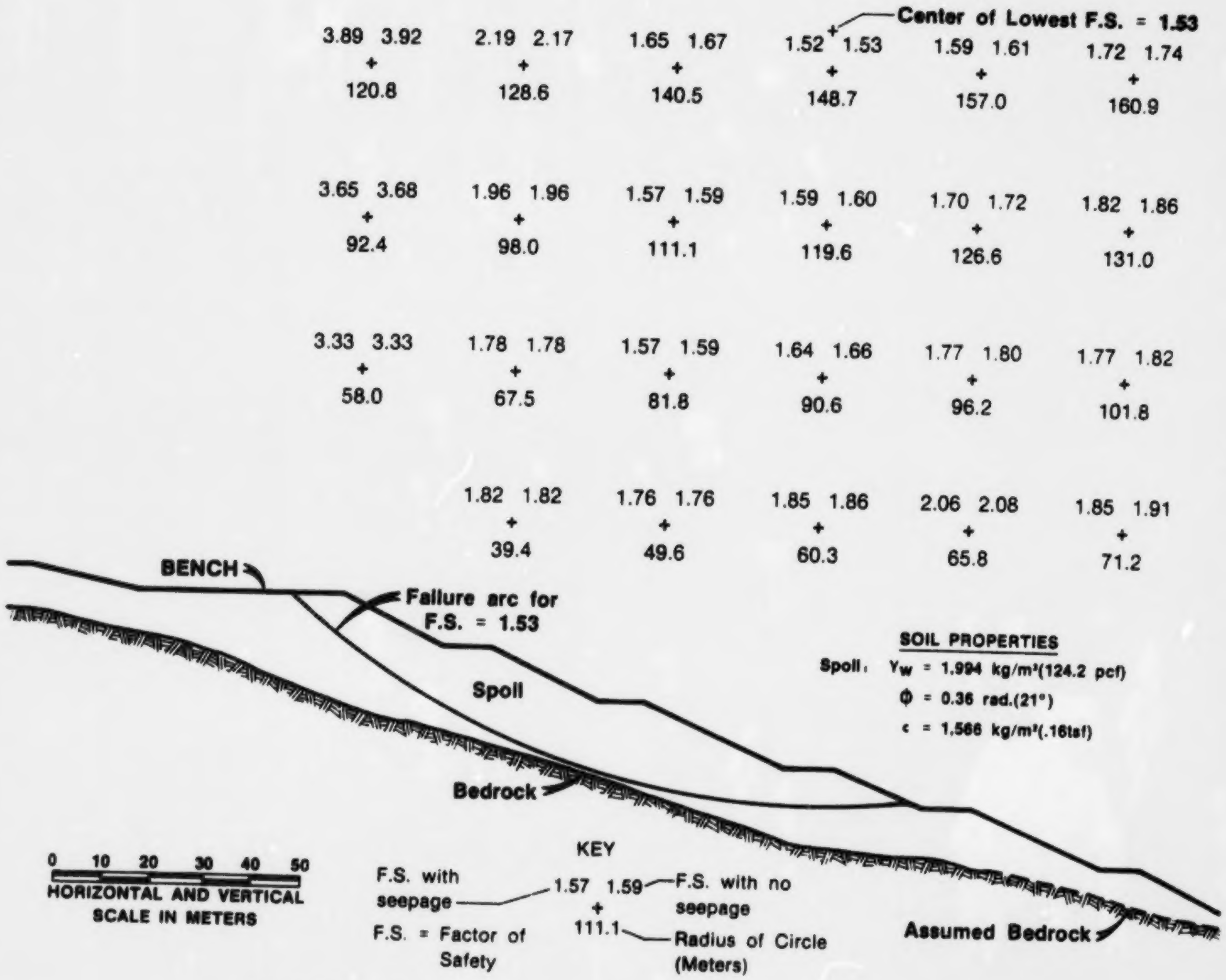

Center of Lowest F.S. = 1.53
3.89 3.92 + 120.8
2.19 2.17 + 128.6
1.65 1.67 + 140.5
1.52 1.53 + 148.7
1.59 1.61 + 157.0
1.72 1.74 + 160.9
3.65 3.68 + 92.4
1.96 1.96 + 98.0
1.57 1.59 + 111.1
1.59 1.60 + 119.6
1.70 1.72 + 126.6
1.82 1.86 + 131.0
3.33 3.33 + 58.0
1.78 1.78 + 67.5
1.57 1.59 + 81.8
1.64 1.66 + 90.6
1.77 1.80 + 96.2
1.77 1.82 + 101.8
1.82 1.82 + 39.4
1.76 1.76 + 49.6
1.85 1.86 + 60.3
2.06 2.08 + 65.8
1.85 1.91 + 71.2
BENCH
Failure arc for F.S. = 1.53
Spoil
Bedrock
Assumed Bedrock
SOIL PROPERTIES
Spoil: Yw = 1,994 kg/m³(124.2 pcf)
ϕ = 0.36 rad.(21°)
c = 1,566 kg/m²(.16tsf)
0 10 20 30 40 50
HORIZONTAL AND VERTICAL SCALE IN METERS
KEY
F.S. with seepage
1.57 1.59 + 111.1
F.S. with no seepage
Radius of Circle (Meters)
F.S. = Factor of Safety

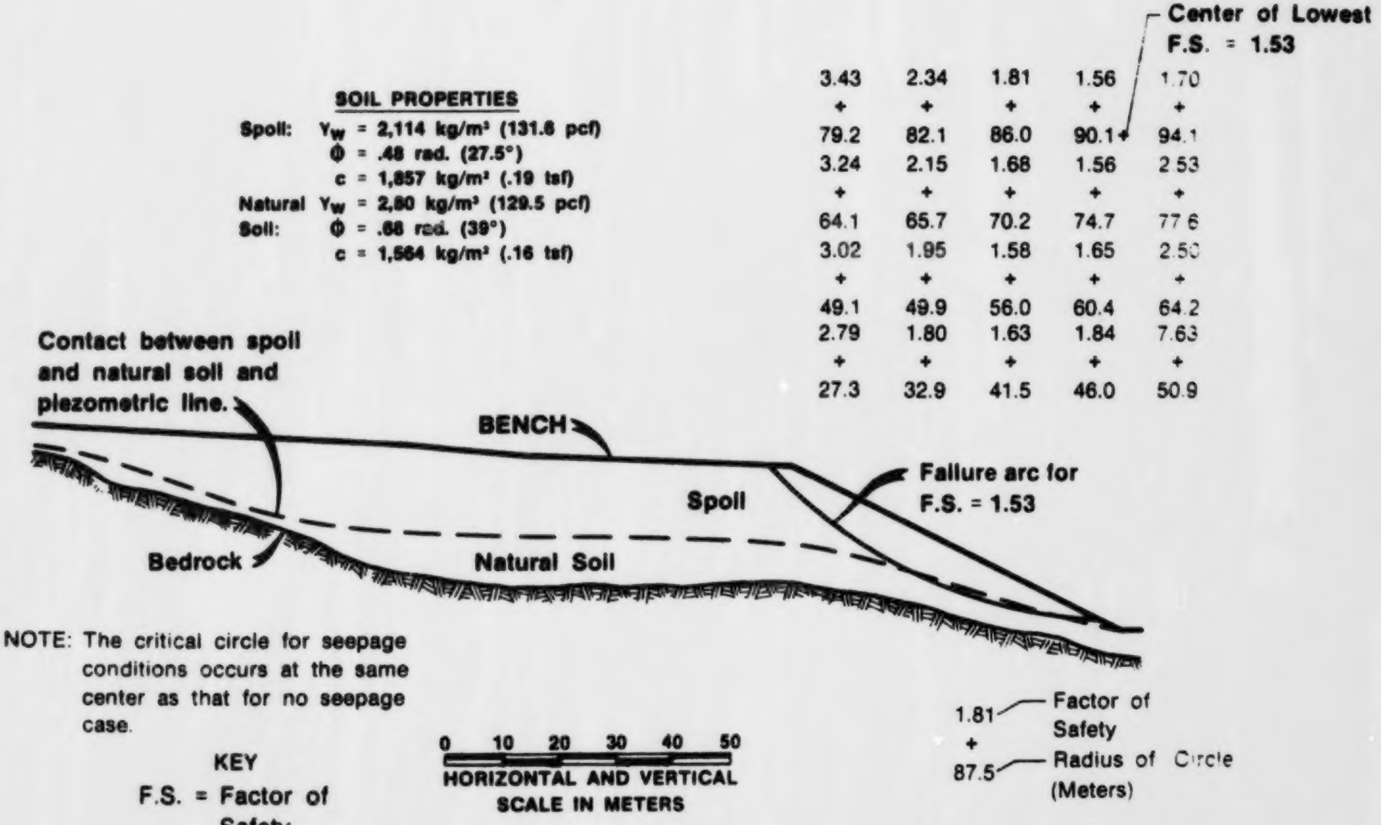
FIGURE 18. Slope stability analysis - site SpS.

19, respectively. Figure 20 shows only the critical areas for Site B since the grid pattern which resulted in circles with radii long enough to include the entire slope could not be accommodated on the exhibit.

In summary, the results of the analyses for the strength parameters and assumed ground water conditions are as follows:

| Site | Lowest Factor of Safety<br>With Seepage | <br>Without Seepage |
|---|---|---|
| Sp | 1.17 | 1.17 |
| SpS | 1.52 | 1.53 |
| B | 2.50 | 2.93 |
| Bu | 1.53 | 1.53 |

The stability calculations show that the four embankments studied are safe. Three of the embankments meet or exceed the OSM requirements of a factor of safety of 1.5 under static conditions. At Site Sp, the lowest factor computed was for a circle passing through a lower steep bench. Generally, the remainder of the circles in the grid had factors of safety greater than 1.2 for both the seepage and non-seepage condition.


Center of Lowest
F.S. = 1.53
3.43
+
79.2
2.34
+
82.1
1.81
+
86.0
1.56
+
90.1
1.70
+
94.1
3.24
+
64.1
2.15
+
65.7
1.68
+
70.2
1.56
+
74.7
2.53
+
77.6
3.02
+
49.1
1.95
+
49.9
1.58
+
56.0
1.65
+
60.4
2.50
+
64.2
2.79
+
27.3
1.80
+
32.9
1.63
+
41.5
1.84
+
46.0
7.63
+
50.9
Contact between spoil and natural soil and piezometric line.
BENCH
Spoil
Failure arc for F.S. = 1.53
Bedrock
Natural Soil
0
10
20
30
40
50
HORIZONTAL AND VERTICAL SCALE IN METERS
1.81
+
87.5
Factor of Safety
Radius of Circle (Meters)

**SOIL PROPERTIES**

**Spoil:** $\gamma_w$ = 2,114 kg/m³ (131.6 pcf)
$\Phi$ = .48 rad. (27.5°)
c = 1,857 kg/m² (.19 tsf)

**Natural Soil:** $\gamma_w$ = 2,80 kg/m³ (129.5 pcf)
$\Phi$ = .68 rad. (39°)
c = 1,564 kg/m² (.16 tsf)

NOTE: The critical circle for seepage conditions occurs at the same center as that for no seepage case.

KEY
F.S. = Factor of Safety

**FIGURE 19. Slope stability analysis - site Bu.**

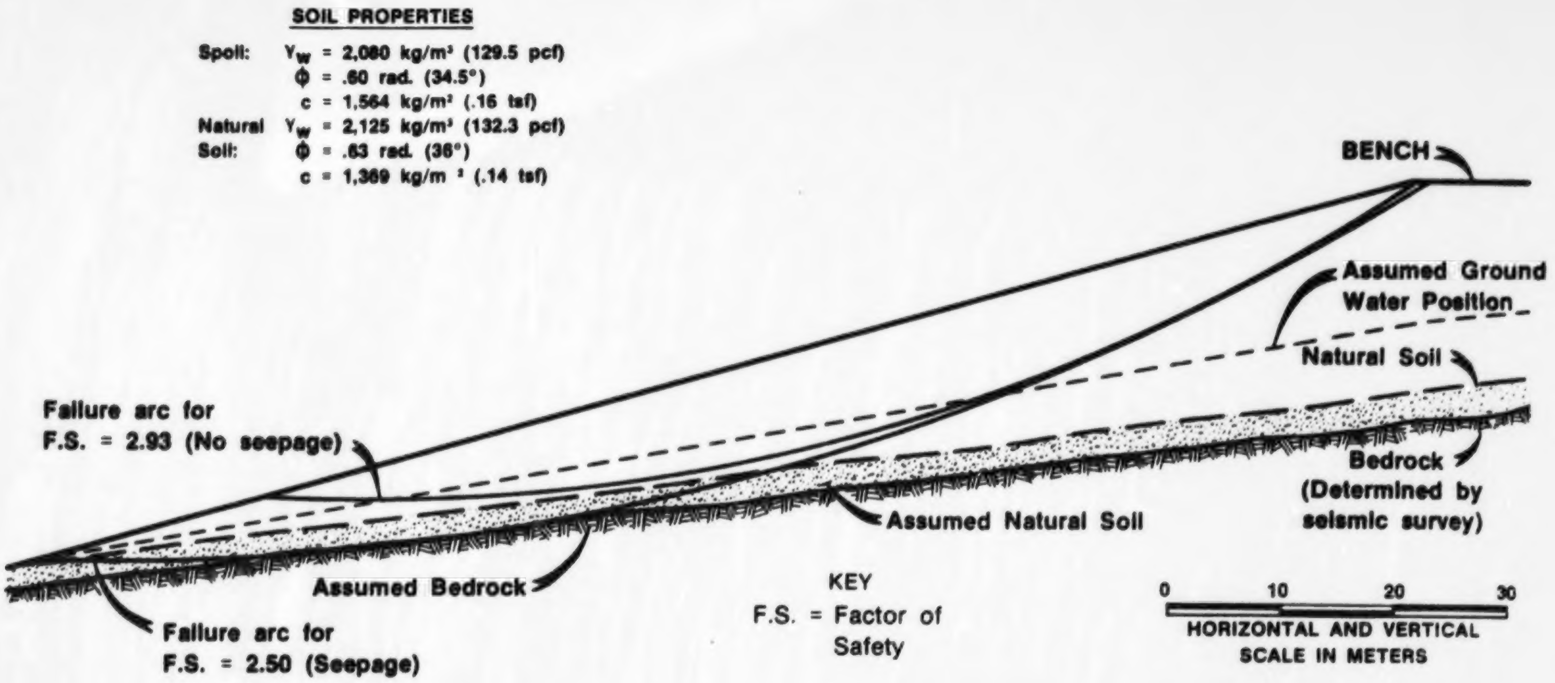
 
SOIL PROPERTIES
Spoil: $\gamma_w$ = 2,080 kg/m³ (129.5 pcf)
$\phi$ = .60 rad. (34.5°)
c = 1,564 kg/m² (.16 tsf)
Natural Soil: $\gamma_w$ = 2,125 kg/m³ (132.3 pcf)
$\phi$ = .63 rad. (36°)
c = 1,369 kg/m ² (.14 tsf)
BENCH
Assumed Ground Water Position
Natural Soil
Bedrock (Determined by seismic survey)
Failure arc for F.S. = 2.93 (No seepage)
Assumed Natural Soil
Assumed Bedrock
Failure arc for F.S. = 2.50 (Seepage)
KEY
F.S. = Factor of Safety
0
10
20
30
HORIZONTAL AND VERTICAL SCALE IN METERS

FIGURE 20. Slope stability analysis - site B.

# SECTION 8
# ANALYSIS OF ROCK CHIMNEY DRAINS

Rock chimney drains are an integral part of only two of the four fills in this study. They are sites Sp and SpS which are located in West Virginia. The first step in our approach to evaluating the water carrying capacity of the drains was to determine whether water entering the drain at the top of the fill was the same water that was exiting at the toe of the fill. Our plan was to pour fluorescein dye into the water entering the fill on the platform and to estimate the outflow.

As it turned out, there were several flaws in the proposed plan:

- It was necessary to depend on natural rainfall to provide the water to make the measurements. On at least two occasions after a few days of rain, the amount of surface water entering the drain was negligible.
- The nature and size of the drainage areas above the fills was such that very little water ever reached the drainage pocket.
- The topographic conditions resulting after backfilling of the highwall and the pattern of the haul roads provided interceptors which prevented water from reaching the drains. Most of this water probably reached the drains by flowing underground.
- When the dye was used there was only a trickle of water entering the drains. There was no evidence of the dye in the water at the toe of the slope even after a period of several hours.

The visible rock in the chimney drain is primarily hard, fine grained sandstone. It is assumed that the sandstone is consistent for the entire depth of the fill. Some of the boulders in the drains have nominal sizes of at least 3.6 m (8 ft.). The interstitial space among the boulders, within the depth limits which we could observe, is free of any extremely small particles. Several large shale boulders which show considerable degradation are situated in the top of fill drainage pockets. The drainage pocket also has an accumulation of fine soil within it.

Drilling through the rock cores was a task which neither of the drilling firms would attempt. The lack of filler material and the precarious position of many of the boulders was of serious concern to them. The operators feared that they would lose their diamond drilling tools if they attempted drilling through the boulders.

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Designation: D423-66, Standard Test Method for Liquid Limit of Soils.

Designation: D424-59, Standard Test Method for Plastic Limit and Plasticity Index of Soils.

Designation: D1140-54, Test for Amount of Material in Soils Finer than the No. 200 (75 M) Sieve.

Designation: D1586-67, STandard Method for Penetration Test and Split Barrel Sampling of Soils.

Designation: D2113-70, Diamond Core Drilling for Site Investigation

Designation: D2216-71, Laboratory Determination of Moisture Content of Soil.

Designation: D2487-69, Classification of Soils for Engineering Purposes.

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Mooney, Harold, M., 1980, Handbook of Engineering Geophysics, Volume 2 Electrical Resistivity, Bison Instruments, Inc. 5708, W. 36th Street, Minn. Mn 55416.

Figure A-1. Boring Sp-1.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING Sp-1 | |
| | | | 12.5 | 1809 | | | | | 0 | 6 | SM (vis) | Br. and gr. sandy clay with Ss frags. 1.22 |
| 22 | 24 | 6 | 6.7 | | | | | | 1.52 | 13 | GM/ GC | Gr. shale with sandstone and clay |
| | | | 11.8 | | | | | | 3.05 | 11 | CL (vis) | |
| | | | 11.3 | | | | | | 4.57 | 27 | GM/ GC (vis) | 6.10 |
| | | | 15.1 | | | | | | 6.10 | 26 | SM (vis) | Br. and gr. sandy clay with shale, coal and sandstone frags. |
| 50 | 30 | 10 | 11.6 | 1812 | | | | | 7.62 | 11 | CL | |
| | | | 14.0 | | | | | | 9.14 | 14 | CL (vis) | Boulders<br>6.55-7.01<br>8.23-8.84 |
| | | | 15.4 | | | | | | 10.67 | 24 | SM (vis) | Water seepage noted at 6.1 m and 12.2 m |
| | | | 11.0 | | | | | | 12.19 | 43 | CL (vis) | |
| | | | 6.5 | | | | | | 13.72 | 23 | GM/ GC (vis) | |
| | | | 15.7 | | | | | | 15.24 | 22 | CL (vis) | |
| | | | 13.6 | | | | | | 16.76 | 20 | CL (vis) | 18.29 |
| | | | 15.7 | | | | | | 18.29 | 19 | SM (vis) | Br. and gr. sandy clay with sandstone frags. |
| | | | 11.4 | | | | | | 19.81 | 75 | SM (vis) | |
| | | | 12.1 | | | | | | 21.34 | 69 | SM (vis) | |

Figure A-1 (continued). Boring Sp-1.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING Sp-1 (Cont'd.) | |
| | | | 11.0 | | | | | | 0 | 69 | SM (vis) | |
| | | | 9.9 | | | | | | 1.52 | 40 | SM (vis) | |
| | | | 12.0 | | | | | | 3.05 | 36 | SM (vis) | |
| 32 | 17 | 2 | 11.5 | | | | | | 4.57 | 48 | SM | 28.19 |
| | | | | | | | | | 6.10 | (97%) | | Br. and gr. sandstone<br>29.72 |
| | | | | | | | | | 7.62 | | | End of Boring at 29.72 m. |
| | | | | | | | | | 9.14 | | | |
| | | | | | | | | | 10.67 | | | |
| | | | | | | | | | 12.19 | | | |
| | | | | | | | | | 13.72 | | | |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | | | |
| | | | | | | | | | 18.29 | | | |
| | | | | | | | | | 19.81 | | | |
| | | | | | | | | | 21.34 | | | |

## Figure A-2. Boring Sp-2.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING Sp 2 | |
| | | | 10.9 | | | | | | 0 | 22 | SM (vis) | Br. and gr. shale and sandstone fragments with clay - trace of coal |
| | | | 9.8 | | | | | | 1.52 | 16 | GM/GC (vis) | |
| | | | 10.9 | | | | | | 3.05 | 10 | CL (vis) | |
| | | | 7.9 | | | | | | 4.57 | 9 | GM/GC (vis) | |
| 31 | 26 | 7 | 11.4 | | | | | | 6.10 | 9 | SM/SC | Seepage at 7.62 m and 10.7 m |
| 18 | 19 | NP | 11.0 | | | | | | 7.62 | 29 | SM | |
| | | | 18.2 | 1689 | | | | | 9.14 | 14 | CL (vis) | |
| 39 | 24 | 7 | 17.1 | | | | | | 10.67 | 6/.5 | SM/SC | |
| 29 | 30 | 10 | 15.3 | | | | | | 12.19 | 21 | GC | |
| | | | 7.9 | | | | | | 13.72 | 49 | GM/GC (vis) | |
| | | | 14.6 | | | | | | 15.24 | 41 | SM (vis) | 15.24<br>Br. clayey fine sand with clay layers and sandstone fragments |
| | | | 11.11 | | | | | | 16.76 | 80 | SM (vis) | |
| | | | 10.27 | | | | | | 18.29 | 52 | SM (vis) | |
| | | | 11.1 | 2049 | | | | | 19.81 | 47 | SM (vis) | |
| | | | 11.7 | | | | | | 21.34 | 24 | SM (vis) | |

Figure A-2 (continued). Boring Sp-2.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING Sp-2 (Cont'd.) | |
| 37 | 19 | 2 | 11.8 | | | | | | 0 | 44 | SM | |
| | | | 13.1 | 2009 | | | | | 1.52 | 28 | SM<br>(vis) | 24.69<br>Br. and gr. sandstone and sandy shale<br>26.2 |
| | | | | | | | | | 3.05 | (70%) | | End of Boring at 26.2 m. |
| | | | | | | | | | 4.57 | | | |
| | | | | | | | | | 6.10 | | | |
| | | | | | | | | | 7.62 | | | |
| | | | | | | | | | 9.14 | | | |
| | | | | | | | | | 10.67 | | | |
| | | | | | | | | | 12.19 | | | |
| | | | | | | | | | 13.72 | | | |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | | | |
| | | | | | | | | | 18.29 | | | |
| | | | | | | | | | 19.81 | | | |
| | | | | | | | | | 21.34 | | | |

## Figure A-3. Boring Sp-3.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | BORING Sp-3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | | |
| | | | 8.4 | | | | | | 0 | 16 | GM/ GC | |
| | | | 5.3 | | | | | | 1.52 | 17 | GM/ GC (vis) | |
| | | | 7.6 | | | | | | 3.05 | 13 | GM/ GC (vis) | Shale and sandstone with clay |
| 31 | 23 | 6 | 12.2 | | | | | | 4.57 | 18 | GM/ GC | Boulders<br>2.29-2.59<br>12.19-12.80 |
| | | | 10.5 | | | | | | 6.10 | 21 | GM/ GC (vis) | |
| | | | 14.7 | 1603 | | | | | 7.62 | 13 | GC (vis) | |
| | | | 13.3 | | | | | | 9.14 | 8 | GC (vis) | |
| | | | 7.6 | | | | | | 10.67 | 12 | GM/ GC (vis) | |
| | | | 9.7 | | | | | | 12.19 | 54 | SM (vis) | 12.80 |
| | | | 7.7 | | | | | | 13.72 | 54 | SM (vis) | Br. and gr. weathered sandstone with clay |
| 35 | 18 | NP | 8.7 | 1939 | | | | | 15.24 | 93 | SM | |
| | | | 8.7 | | | | | | 16.76 | 82 | SM (vis) | |
| | | | 7.4 | | | | | | 18.29 | 85 | SM (vis) | 19.35 |
| | | | | | | | | | 19.81 | (100%) | | Br. and gr. sandstone<br>20.88 |
| | | | | | | | | | 21.34 | | | End of Boring at 20.88 m. |

## Figure A-4. Boring SpS-1.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | DEPTH (Meters) | SPT-N | BORING SpS-1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | | | | |
| 33 | 23 | 5 | 8.5 | | | | | | 0 | 33 | GM/ GC | Br. sandy silt with rock fragments; dry |
| | | | 4.0 | | | | | | 1.52 | 16 | GM (vis) | |
| 26 | 20 | 3 | 6.8 | | | | | | 3.05 | 47 | SM | 4.0 |
| | | | | | | | | | 4.57 | | | |
| 5 | NP | NP | 6.9 | | | | | | 6.10 | 12 | GM | Sandstone boulders. Ranging in size from 5 cm to greater than 30 cm. Thin zones of sand and silt. |
| | | | | | | | | | 7.62 | | | |
| 21 | 21 | 5 | 9.8 | | | | | | 9.14 | 59/.6 | GM/ GC | |
| | | | 4.4 | | | | | | 10.67 | 36 | SM (vis) | |
| | | | | | | | | | 12.19 | 50/.2 | | Boulders |
| | | | | | | | | | 13.72 | | | |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | 50/.3 | | 18.29 |
| 22 | 23 | 7 | 4.2 | | | | | | 18.29 | 61 | GM/ GC | Br. sand & silt with shale rock frags.<br>19.51 |
| | | | | | | | | | 19.81 | 179 | | Br. sandstone with soft seams<br>20.73 |
| | | | | | | | | | 21.34 | | | |

Figure A-4 (continued). Boring SpS-1.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING SpS-1 (Cont'd.) |
| | | | | | | | | | 0 | | 20.73 |
| | | | | | | | | | 1.52 | 100% | Br. with some gr. sandstone |
| | | | | | | | | | 3.05 | 100% | 23.77 |
| | | | | | | | | | 4.57 | | End of Boring at 23.77 m. |
| | | | | | | | | | 6.10 | | |
| | | | | | | | | | 7.62 | | |
| | | | | | | | | | 9.14 | | |
| | | | | | | | | | 10.67 | | |
| | | | | | | | | | 12.19 | | |
| | | | | | | | | | 13.72 | | |
| | | | | | | | | | 15.24 | | |
| | | | | | | | | | 16.76 | | |
| | | | | | | | | | 18.29 | | |
| | | | | | | | | | 19.81 | | |
| | | | | | | | | | 21.34 | | |

## Figure A-5. Boring SpS-2.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING SpS-2 | |
| | | | 5.1 | | | | | | 0 | 39 | GM/GC | Br. sand with some silt and rock frags. |
| | | | 13.8 | | | | | | 1.52 | 7 | GM/GC (vis) | |
| 32 | 22 | 5 | 12.8 | 1905 | | | | | 3.05 | 58/.5 | | 3.20 |
| | | | | | | | | | | | | Boulders |
| | | | 11.2 | | | | | | 4.57 | 67/.7 | GM/GC (vis) | |
| | | | 10.4 | | | | | | 6.10 | | | 6.71 |
| | | | | | | | | | 7.62 | 65/.5 | GM/GC (vis) | Br. sand with small boulders |
| | | | | | | | | | | | | 8.69 |
| | | | | | | | | | 9.14 | | | Br. and gr. sandstone |
| | | | | | | | | | 10.67 | | | Soft seam 9.6 m-10.5 m |
| | | | | | | | | | 12.19 | | | |
| | | | | | | | | | 13.72 | | | 13.72 |
| | | | | | | | | | | | | End of Boring at 13.72 m. |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | | | |
| | | | | | | | | | 18.29 | | | |
| | | | | | | | | | 19.81 | | | |
| | | | | | | | | | 21.34 | | | |

## Figure A-6. Boring SpS-3.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | DEPTH (Meters) | SPT-N | BORING SpS-3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | | | | |
| | | | 4.9 | | | | | | 0 | 51 | GL (vis) | Br. sandy silt with some small boulders |
| 51 | 27 | 8 | 12.3 | | | | | | 1.52 | 39 | CL | 2.44 |
| | | | | | | | | | 3.05 | | | Small boulders with sand<br>4.57 |
| 10 | NP | NP | 9.4 | | | | | | 4.57 | 27 | GM/GC | Br. sand with some silt & rock frags. 5.49 |
| | | | | | | | | | 6.10 | | | Boulders<br>7.62 |
| | | | | | | | | | 7.62 | | | Gray clayey shale 8.26<br>Coal 8.35 |
| | | | | | | | | | 9.14 | | | Gray sandstone - hard<br>10.67 |
| | | | | | | | | | 10.67 | 100% | | End of Boring at 10.67 m. |
| | | | | | | | | | 12.19 | | | |
| | | | | | | | | | 13.72 | | | |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | | | |
| | | | | | | | | | 18.29 | | | |
| | | | | | | | | | 19.81 | | | |
| | | | | | | | | | 21.34 | | | |

## Figure A-7. Boring B-1.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING B-1 | | |
| | | | | | | | | | 0 | | | | |
| | | | 18.4 | | | | | | | 10 | CL/ML (vis) | Br. and gr. sandy clay with sandstone and shale frags. | |
| 56 | 30 | 7 | 21.6 | | | | | | | 3 | CL/ML | | |
| | | | | | | | | | 1.52 | | | | |
| | | | 20.7 | | | | | | | 2 | CL/ML (vis) | | |
| | | | 14.8 | | | | | | | 5 | CL/ML (vis) | | |
| | | | 19.4 | | | | | | 3.05 | 52/.5 | CL/ML (vis) | | |
| | | | 21.4 | | | | | | 4.57 | 4 | CL/ML (vis) | | |
| | | | 16.7 | | | | | | 6.10 | 10 | SW (vis) | | |
| | | | 12.7 | | | | | | 7.62 | 27 | SW (vis) | | 8.53 |
| | | | 15.5 | | | | | | 9.14 | 15 | SM (vis) | Br. and yel. sandy clay with small boulder | 10.06 |
| | | | 12.9 | | | | | | 10.67 | 19 | SM (vis) | Br. and tn. sandy, silty clay with boulders | 11.28 |
| | | | 14.1 | | | | | | 12.19 | 17 | SM (vis) | Br. and yel. sandy clay with sand streaks and small boulders | |
| | | | | | | | | | 13.72 | 26 | SM (vis) | | 14.94 |
| | | | | | | | | | 15.24 | 43 | SM (vis) | Tn. and br. clay | |
| | | | | | | | | | 16.76 | 50/0 | | | 16.76 |
| | | | | | | | | | | | | Weathered shale | 18.29 |
| | | | | | | | | | 18.29 | 100% | | Gray shale with clay seams - soft to hard | |
| | | | | | | | | | 19.81 | | | | 21.34 |
| | | | | | | | | | 21.34 | 100% | | Gray shale with coal seams - soft | |

Figure A-8. Boring B-2.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING B-2 | |
| 40 | 28 | 6 | 16.7 | 1691 | | | | | 0 | 3 | SM/ SC | Br. and gr. sandy clay with small shale and sandstone boulders |
| | | | 17.8 | 1861 | | | | | | 37 | SM/ SC (vis) | |
| | | | 14.0 | | | | | | 1.52 | 24 | SM/ SC (vis) | |
| | | | 19.4 | | | | | | 3.05 | 6<br>3 | SM/ SC (vis)<br>SM/ SC (vis) | |
| | | | 24.6 | | | | | | 4.57 | 5 | SW (vis) | |
| | | | 18.2 | | | | | | 6.10 | 7 | SW (vis) | |
| | | | | | | | | | 7.62 | 28 | SW | |
| | | | | | | | | | | | | 8.38 |
| | | | | | | | | | 9.14 | 16 | | Br. and yel. sandy clay with weathered shale |
| | | | 16.7 | | | | | | 10.67 | 17 | SW (vis) | |
| | | | | | | | | | | | | 11.89 |
| 41 | 19 | 2 | 13.6 | 1905 | | | | | 12.19 | 65 | SW | Br. sandy clay with weathered shale |
| 23 | 16 | NP | 14.3 | | | | | | 13.72 | 47 | SM | |
| | | | 20.2<br>20.2 | 1715<br>1745 | | | | | 15.24 | 30 | | |
| | | | 17.2 | 1810 | | | | | 16.76 | 25 | SM/ SC (vis) | |
| | | | | | | | | | | | | 17.83 |
| | | | | | | | | | 18.29 | | | Weathered shale |
| | | | | | | | | | | | | 19.05 |
| | | | | | | | | | 19.81 | | | Br. sandy clay with weathered shale |
| | | | | | | | | | | | | 20.73 |
| | | | | | | | | | 21.34 | | | Weathered shale |
| | | | | | | | | | | | | 21.64 |

Figure A-8 (continued). Boring B-2.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING B-2 (Cont'd.) |
| | | | | | | | | | 0 | | Gr. shale moderately hard to hard<br>24.69 |
| | | | | | | | | | 1.52 | (100%) | |
| | | | | | | | | | 3.05 | | |
| | | | | | | | | | 4.57 | | |
| | | | | | | | | | 6.10 | | |
| | | | | | | | | | 7.62 | | |
| | | | | | | | | | 9.14 | | |
| | | | | | | | | | 10.67 | | |
| | | | | | | | | | 12.19 | | |
| | | | | | | | | | 13.72 | | |
| | | | | | | | | | 15.24 | | |
| | | | | | | | | | 16.76 | | |
| | | | | | | | | | 18.29 | | |
| | | | | | | | | | 19.81 | | |
| | | | | | | | | | 21.34 | | |

## Figure A-9. Boring B-3.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING B-3 | |
| | | | 10.1 | 1984 | | | | | 0 | 80/.5 | SM/SC | (vis) |
| | | | 17.1 | | | | | | | 1.1 | | |
| | | | | | | | | | 1.52 | | | |
| | | | 13.7 | | | | | | | 8 | SM/SC | (vis) |
| 37 | 22 | 5 | 17.6 | | | | | | | 7 | SM/SC | (vis) |
| | | | | | | | | | 3.05 | 7 | SM/SC | Gr. & br. sandy clay with small boulders |
| | | | 18.6 | | | | | | 4.57 | 7 | SM/SC (vis) | |
| 24 | 21 | NP | 15.7 | | | | | | 6.10 | 9 | GM | |
| | | | 17.2 | | | | | | 7.62 | 23 | SM (vis) | |
| | | | 19.2 | 1762 | | | | | 9.14 | 14 | SM/SC (vis) | |
| | | | | | | | | | 10.67 | 8 | SM/SC (vis) | 11.58 |
| | | | 15.7 | 1891 | | | | | 12.19 | 31 | SW (vis) | Coal fill<br>12.19 |
| | | | 17.3 | 1777 | | | | | 13.72 | 80/.5 | SW (vis) | Gr. & br. sandy clay with shale and sandstone boulders |
| | | | 17.3 | 1734 | | | | | | | | |
| | | | 17.3 | 1726 | | | | | | | | |
| | | | 18.8 | | | | | | 15.24 | 58/.8 | GM (vis) | |
| | | | 14.8 | | | | | | 16.76 | 9 | GM (vis) | |
| | | | | | | | | | 18.29 | 7 | | 18.29<br>Large boulders |
| 50 | 24 | 5 | 16.8 | | | | | | 19.81 | 65 | SM/SC | 19.81<br>Large boulders and metal debris |
| | | | | | | | | | 21.34 | | | |
| | | | | | | | | | | | | 22.40 |

Figure A-9 (continued). Boring B-3.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING B 3 (Cont'd.) |
| | | | | | | | | | 0 | | Gn. and gr. clayey sand<br>24.26 |
| | | | | | | | | | 1.52 | | Wthd. sand 24.54<br>Wthd. shale with clay seams<br>25.76 |
| | | | | | | | | | 3.05 | | Gr. sandstone |
| | | | | | | | | | 4.57 | 100% | 27.58<br>End of Boring at 27.58 m. |
| | | | | | | | | | 6.10 | | |
| | | | | | | | | | 7.62 | | |
| | | | | | | | | | 9.14 | | |
| | | | | | | | | | 10.67 | | |
| | | | | | | | | | 12.19 | | |
| | | | | | | | | | 13.72 | | |
| | | | | | | | | | 15.24 | | |
| | | | | | | | | | 16.76 | | |
| | | | | | | | | | 18.29 | | |
| | | | | | | | | | 19.81 | | |
| | | | | | | | | | 21.34 | | |

Figure A-10. Boring B-4.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING B 4 | |
| | | | | | | | | | 0 | | | Boulders 0.46 |
| 41 | 22 | 7 | 13.5 | 1877 | | | | | | 11 | SM/SC | |
| | | | 12.1 | 1981 | | | | | 1.52 | 11 | SM/SC (vis) | Tn., br. and gr. sandy clay with sandstone and shale |
| | | | 15.6 | 1887 | | | | | 3.05 | 6 | GM/GC (vis) | |
| 33 | 27 | 7 | 12.9 | | | | | | 4.57 | 9 | GM/GC (vis) | 5.49 |
| | | | | | | | | | | | | Boulder 5.79 |
| | | | 12.9 | | | | | | 6.10 | 19 | GM/GC (vis) | |
| 47 | 29 | 7 | 16.1 | | | | | | 7.62 | 4 | SM/SC (vis) | Tn. and br. sandy clay with sandstone and shale |
| | | | 18.7 | | | | | | 9.14 | 55/.5 | SM/SC (vis) | |
| | | | 17.2 | | | | | | 10.67 | 7 | SM/SC (vis) | 11.43 |
| | | | | | | | | | | | | Boulder 11.81 |
| | | | 10.7 | | | | | | 12.19 | 13 | SM/SC (vis) | Tn. and br. sandy clay with rock fragments |
| | | | 18.5 | 1834 | | | | | 13.72 | 15 | GM/GC (vis) | 14.63 |
| | | | 13.4 | | | | | | 15.24 | 62 | GM/GC (vis) | Weathered shale |
| | | | | | | | | | 16.76 | | | 17.22 |
| | | | | | | | | | | | | Gr. shale with mud seams 17.45 |
| | | | | | | | | | 18.29 | | | Gr. sandstone m. hd. 18.90 |
| | | | | | | | | | 19.81 | (93%) | | Gr. sandy shale - soft 20.27 |
| | | | | | | | | | | | | End of Boring at 20.27 m. |
| | | | | | | | | | 21.34 | | | |

## Figure A-11. Boring Bu-1.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING Bu-1 | |
| | | | | | | | | | 0 | | | |
| | | | 17.9 | 1886 | | | | | | 17 | GC (vis) | |
| 40 | 23 | 4 | 17.6 | | | | | | 1.52 | 21 | GM/ GC | |
| | | | 14.5 | | | | | | 3.05 | 16 | GM/ GC (vis) | |
| | | | 1.3 | | | | | | 4.57 | 28/.5 | GC (vis) | Gr., tn. and br. sandy clay with shale fragments |
| | | | 16.5 | | | | | | 6.10 | 6 | GC (vis) | |
| 42 | 26 | 8 | 18.9 | | | | | | 7.62 | 13 | GC | |
| | | | 15.8 | | | | | | 9.14 | 12 | SM/ SC (vis) | |
| | | | 4.9 | | | | | | 10.67 | 8 | GC (vis) | |
| | | | 15.2 | | | | | | 12.19 | 9 | GC (vis) | 13.11 |
| | | | | | | | | | | | | Boulder 13.56 |
| | | | | | | | | | 13.72 | | | |
| | | | 12.6 | 1999 | | | | | | 9 | GC (vis) | Gr., tn. and br. sandy clay with shale frags. |
| | | | 1.8 | | | | | | 15.24 | 16 | GC (vis) | 15.39 |
| | | | 1.3 | | | | | | 16.76 | 24 | GC (vis) | Weathered shale<br>17.68 |
| | | | | | | | | | 18.29 | | | Gr. sandstone with shale streaks |
| | | | | | | | | | 19.81 | (22.52) | | 20.72 |
| | | | | | | | | | 21.34 | | | Gr. shale - weathered - soft |

Figure A-11 (continued). Boring Bu-1.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | BORING Bu 1 (Cont'd.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | |
| | | | | | | | | | 0 | | |
| | | | | | | | | | | (42.57) | Gr. shale weathered - soft 23.77 |
| | | | | | | | | | 1.52 | | End of Boring at 23.77 m. |
| | | | | | | | | | 3.05 | | |
| | | | | | | | | | 4.57 | | |
| | | | | | | | | | 6.10 | | |
| | | | | | | | | | 7.62 | | |
| | | | | | | | | | 9.14 | | |
| | | | | | | | | | 10.67 | | |
| | | | | | | | | | 12.19 | | |
| | | | | | | | | | 13.72 | | |
| | | | | | | | | | 15.24 | | |
| | | | | | | | | | 16.76 | | |
| | | | | | | | | | 18.29 | | |
| | | | | | | | | | 19.81 | | |
| | | | | | | | | | 21.34 | | |

## Figure A-12. Boring Bu-2.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | | BORING Bu2 |
| | | | 12.1 | | | | | | 0 | 50/.4 | GW (vis) | |
| 22 | 24 | 8 | 8.6 | | | | | | 1.52 | 20 | GC | |
| | | | 15.8 | 1827 | | | | | 3.05 | 12 | GW (vis) | |
| | | | 16.1 | | | | | | 4.57 | 2 | GW (vis) | |
| | | | 15.8 | 1815 | | | | | 6.10 | 6 | | Gr. and tn. sandy clay with sandstone and shale boulders |
| | | | 37.4 | | | | | | 7.62 | 11 | | |
| | | | 17.0 | | | | | | 9.14 | 9 | SM/SC (vis) | |
| | | | 9.4 | | | | | | 10.67 | 17 | GC (vis) | |
| 30 | 25 | 6 | 15.4 | | | | | | 12.19 | 14 | GW | |
| | | | 12.7 | | | | | | 13.72 | 50/.3 | GW (vis) | 14.78 |
| | | | 15.0 | | | | | | 15.24 | 46 | GW (vis) | Boulders<br>16.30 |
| | | | 12.9 | | | | | | 16.76 | 35 | GW (vis) | |
| | | | 1.2 | | | | | | 18.29 | 34 | GC (vis) | Gr. sandy clay with rock and coal refuse |
| | | | 16.0 | | | | | | 19.81 | 8 | GW (vis) | |
| | | | | | | | | | 21.34 | | | 22.40<br>Boulder<br>22.86 |

Figure A-12 (continued). Boring Bu-2.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING Bu 2 (Cont'd.) | |
| | | | | | | | | | 0 | | | |
| | | | 11.0 | | | | | | 1.52 | 13 | GW | Gr. sandy clay with small shale boulders |
| | | | | | | | | | 3.05 | 18 | GW (vis) | 26.21 |
| | | | 21.5 | 1654 | | | | | 4.57 | 27 | SM/ SC (vis) | Gr. sand with weathered rock fragments |
| 48 | 24 | 5 | 21.6 | 1586 | | | | | 6.10 | 37 | SM/ SC (vis) | |
| | | | 16.2 | | | | | | 7.62 | 20 | SM/ SC | |
| | | | 14.3 | | | | | | 9.14 | 50/.3 | SM/ SC | |
| | | | | | | | | | 10.67 | | | 33.53<br>Gr. sandy shale med. hard |
| | | | | | | | | | 12.19 | | | |
| | | | | | | | | | 13.72 | | | 35.97<br>Gr. sandstone med. hard 36.58<br>End of Boring at 36.58 m. |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | | | |
| | | | | | | | | | 18.29 | | | |
| | | | | | | | | | 19.81 | | | |
| | | | | | | | | | 21.34 | | | |

## Figure A-13. Boring Bu-3.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | DEPTH (Meters) | SPT-N | BORING Bu-3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | | | | |
| | | | | | | | | | 0 | 50/.2 | | Gr. and br. sandy clay with small sandstone and shale boulders |
| 58 | 26 | 7 | 15.5 | | | | | | 1.52 | 17/.5 | CL/ ML | |
| | | | 11.3 | | | | | | 3.05 | 23 | CL/ ML (vis) | |
| | | | 15.3 | | | | | | 4.57 | 9 | GW (vis) | |
| | | | 16.8 | | | | | | 6.10 | 3 | GW (vis) | |
| | | | 14.3 | | | | | | 7.62 | 11 | GW (vis) | |
| | | | 8.5 | | | | | | 9.14 | 9 | GC (vis) | |
| | | | | | | | | | | 50/0 | | |
| | | | | | | | | | 10.67 | | | |
| 40 | 25 | 8 | 14.6 | | | | | | 12.19 | 11 | SC | |
| | | | | | | | | | | | | 12.50 |
| | | | 15.1 | | | | | | 13.72 | 15/.5 | GW (vis) | Boulders 0.2 m. to 0.6 m. in size size |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | | | |
| | | | | | | | | | | | | 17.22 |
| | | | 1.4 | | | | | | 18.29 | 14 | GC (vis) | Gr. sandy clay with shale boulders and coal |
| | | | 11.2 | | | | | | 19.81 | 9/.5 | GC (vis) | |
| 46 | 27 | 8 | 11.3 | 1982 | | | | | 21.34 | 32 | GC | |
| | | | 17.9 | | | | | | | 23 | SM/ SC (vis) | |

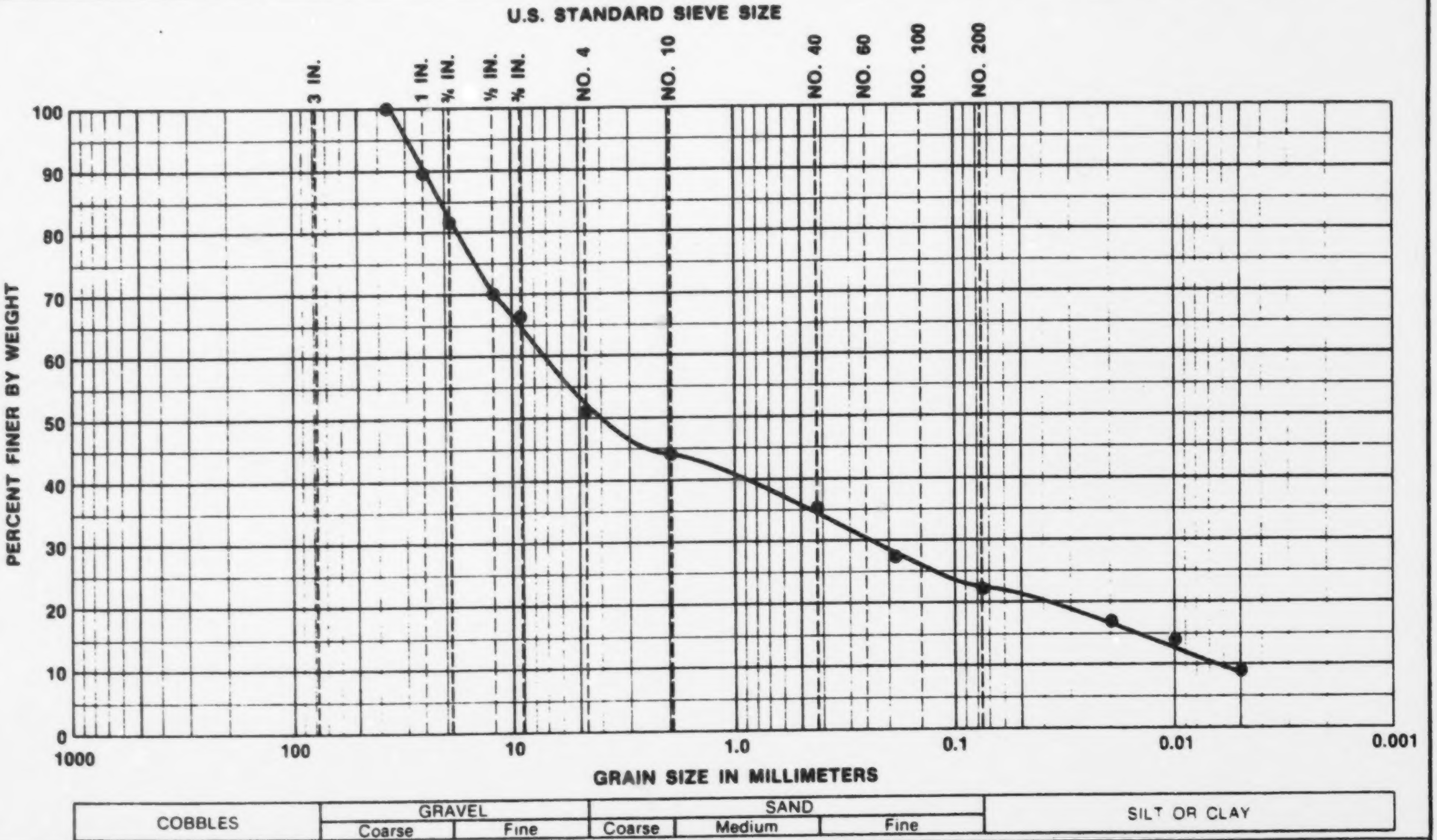
Figure A-13 (continued). Boring Bu-3.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | | BORING Bu-3 (Cont'd.) |
| | | | | | | | | | 0 | | | Gr. sandy clay with shale boulders and coal |
| | | | 12.1 | | | | | | 1.52 | 19/.5 | GC (vis) | |
| | | | 32.3 | | | | | | 3.05 | 12 | GC (vis) | 25.91 |
| | | | | | | | | | | | | Tn., br. and yel. sand with weathered sandstone |
| | | | 16.2 | 1857 | | | | | 4.57 | 27 | SP (vis) | 27.89 |
| | | | | | | | | | | | | Weathered shale - soft<br>28.80 |
| | | | | | | | | | 6.10 | | | Gr. sandy shale - med. hard |
| | | | | | | | | | 7.62 | | | |
| | | | | | | | | | 9.14 | (77%) | | 31.85 |
| | | | | | | | | | | | | End of Boring at 31.85 m. |
| | | | | | | | | | 10.67 | | | |
| | | | | | | | | | 12.19 | | | |
| | | | | | | | | | 13.72 | | | |
| | | | | | | | | | 15.24 | | | |
| | | | | | | | | | 16.76 | | | |
| | | | | | | | | | 18.29 | | | |
| | | | | | | | | | 19.81 | | | |
| | | | | | | | | | 21.34 | | | |

Figure A-14. Boring Bu-4.

| CLASSIFICATION DATA | | | MOISTURE DENSITY DATA | | STRENGTH DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Fines (-No. 200) | Liquid Limit | Plasticity Index | Natural Moisture Content % | Dry Density kg/m³ | Type of Strength Test | Test Surcharge Pressure kg/cm² | Test Moisture Content % | Shear Strength kg/cm² | DEPTH (Meters) | SPT-N | BORING Bu 4 | |
| | | | | | | | | | 0 | | | |
| | | | 13.3 | | | | | | | 11 | SM/SC | (vis) |
| | | | 13.4 | | | | | | 1.52 | 12 | SM/SC (vis) | |
| 23 | NP | NP | 11.9 | | | | | | 3.05 | 12 | SP | |
| | | | 15.8 | | | | | | 4.57 | 17 | SP (vis) | |
| | | | 18.5 | 1778 | | | | | 6.10 | 5 | SM/SC (vis) | |
| | | | 20.5 | | | | | | 7.62 | 4 | SM/SC (vis) | |
| | | | 18.7 | | | | | | 9.14 | 6 | SM/SC (vis) | Br., tn. and gr. sandy clay with small boulders |
| 63 | 23 | 4 | 18.1 | 1704 | | | | | 10.67 | 8 | CL | |
| | | | 16.5 | 1852 | | | | | 12.19 | 8 | SM/SC (vis) | |
| | | | 15.2 | | | | | | 13.72 | 9 | GC (vis) | |
| | | | 4.7 | | | | | | 15.24 | 38 | GC (vis) | |
| | | | 12.0 | | | | | | 16.76 | 11 | GC (vis) | |
| | | | 16.3 | | | | | | 18.29 | 19 | SM/SC (vis) | |
| | | | 15.5 | 1865 | | | | | 19.81 | 13 | SM/SC (vis) | |
| | | | | | | | | | 21.34 | 48 | | 21.49 |
| | | | | | | | | | | | | Trees<br>End of Boring at 22.86 |

Figure B-1. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 1-2 | 1.50-1.98 | GM-GC | 6.7 | 24 | 18 | 6 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

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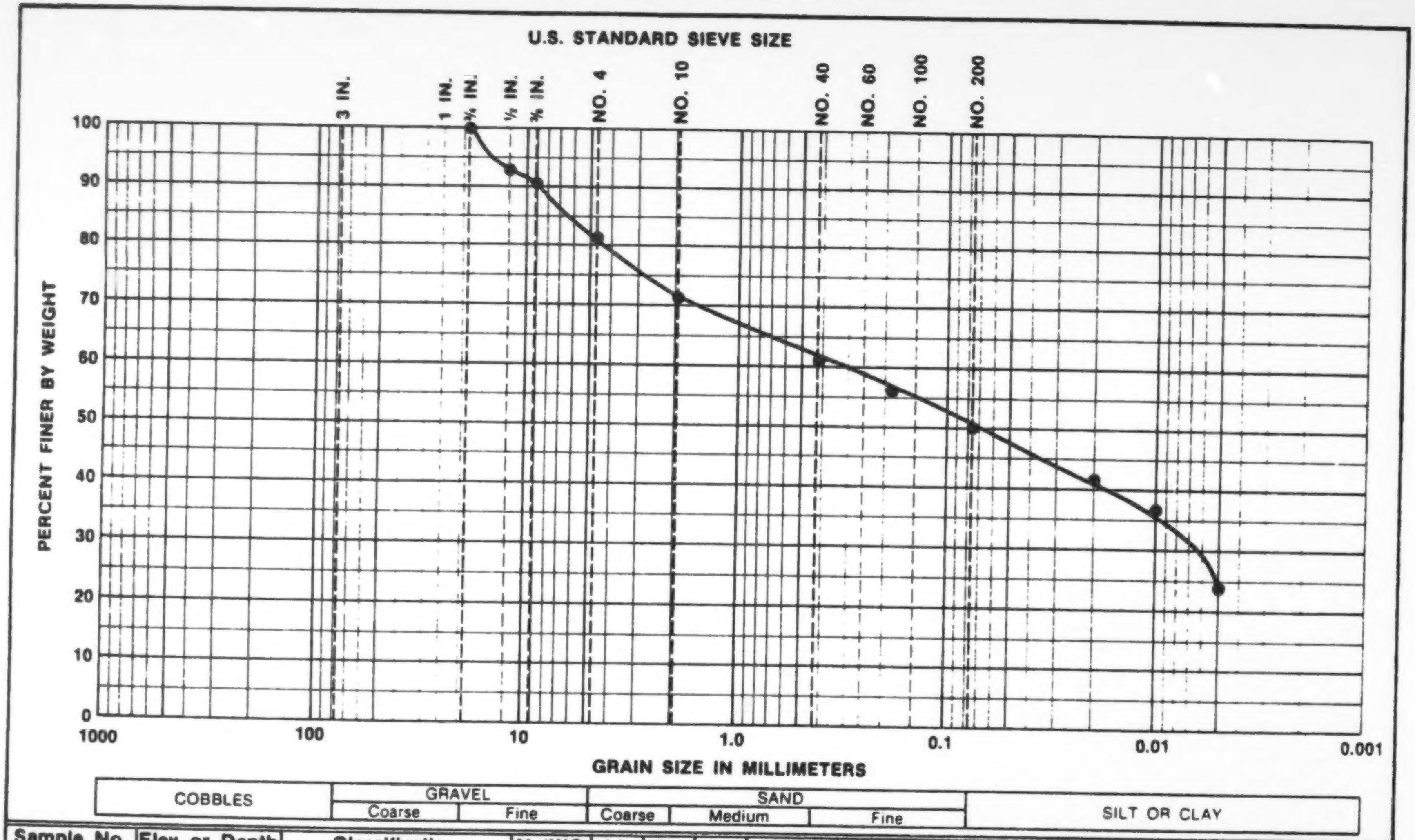
Figure B-2. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 1-6 | 7.62-8.08 | CL | 11.6 | 30 | 20 | 10 | |

**GRADATION CURVES**

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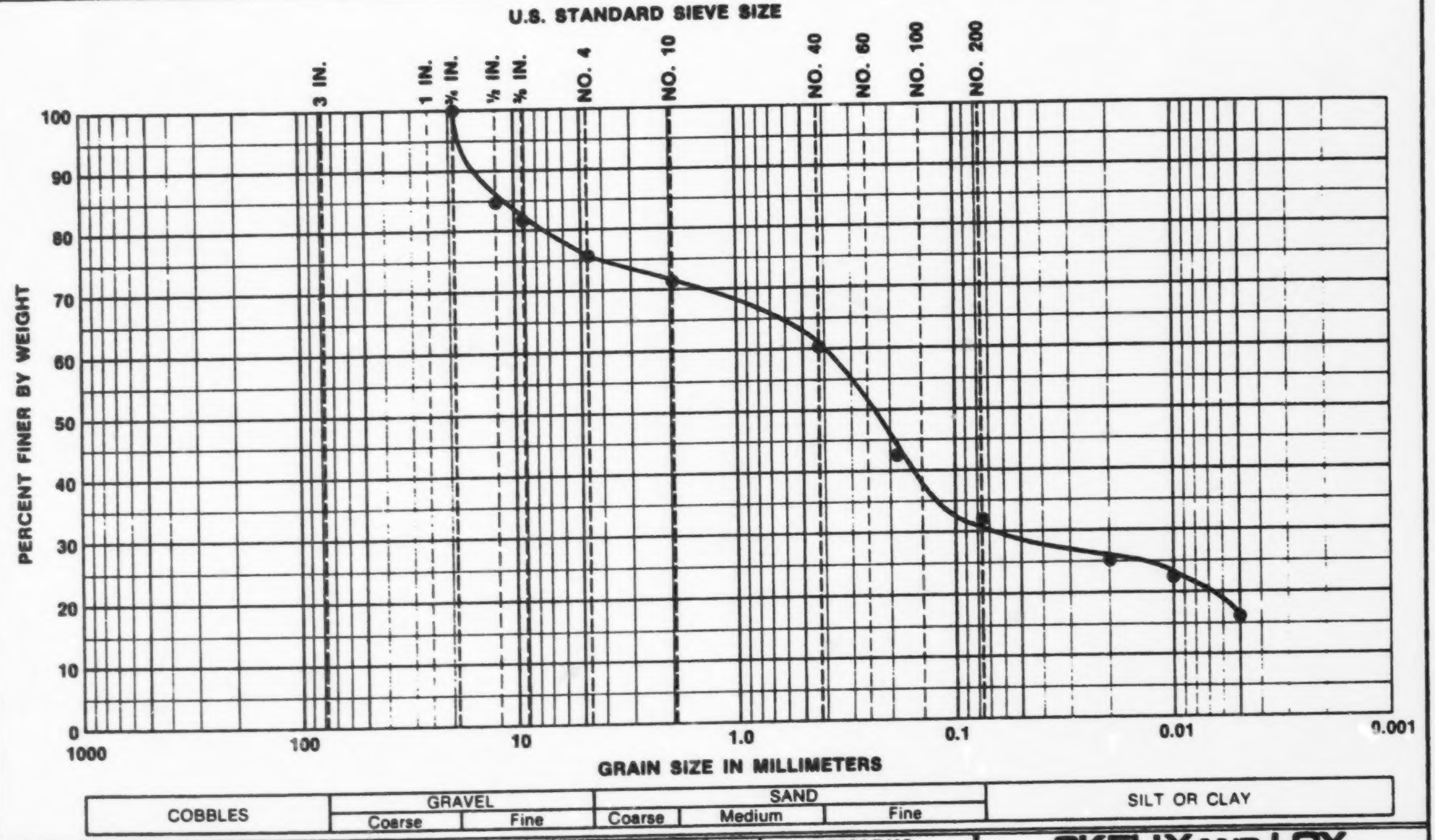
Figure B-3. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 1-19 | 27.43-27.89 | SM | 11.5 | 17 | 15 | 2 | |

**GRADATION CURVES**

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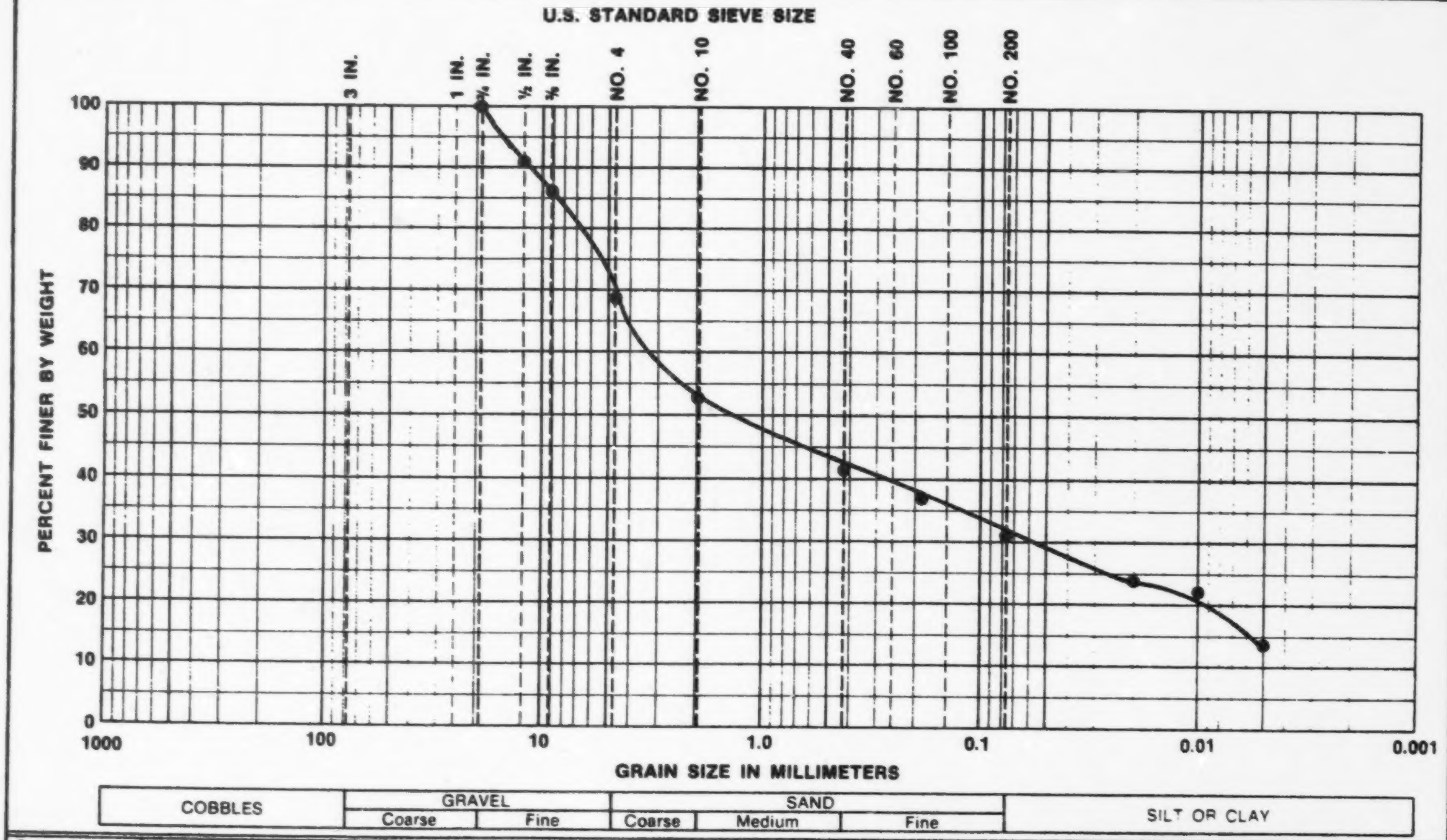
Figure B-4. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 2-5 | 6.1-6.55 | SM-SC | 11.4 | 26 | 19 | 7 | |

**GRADATION CURVES**

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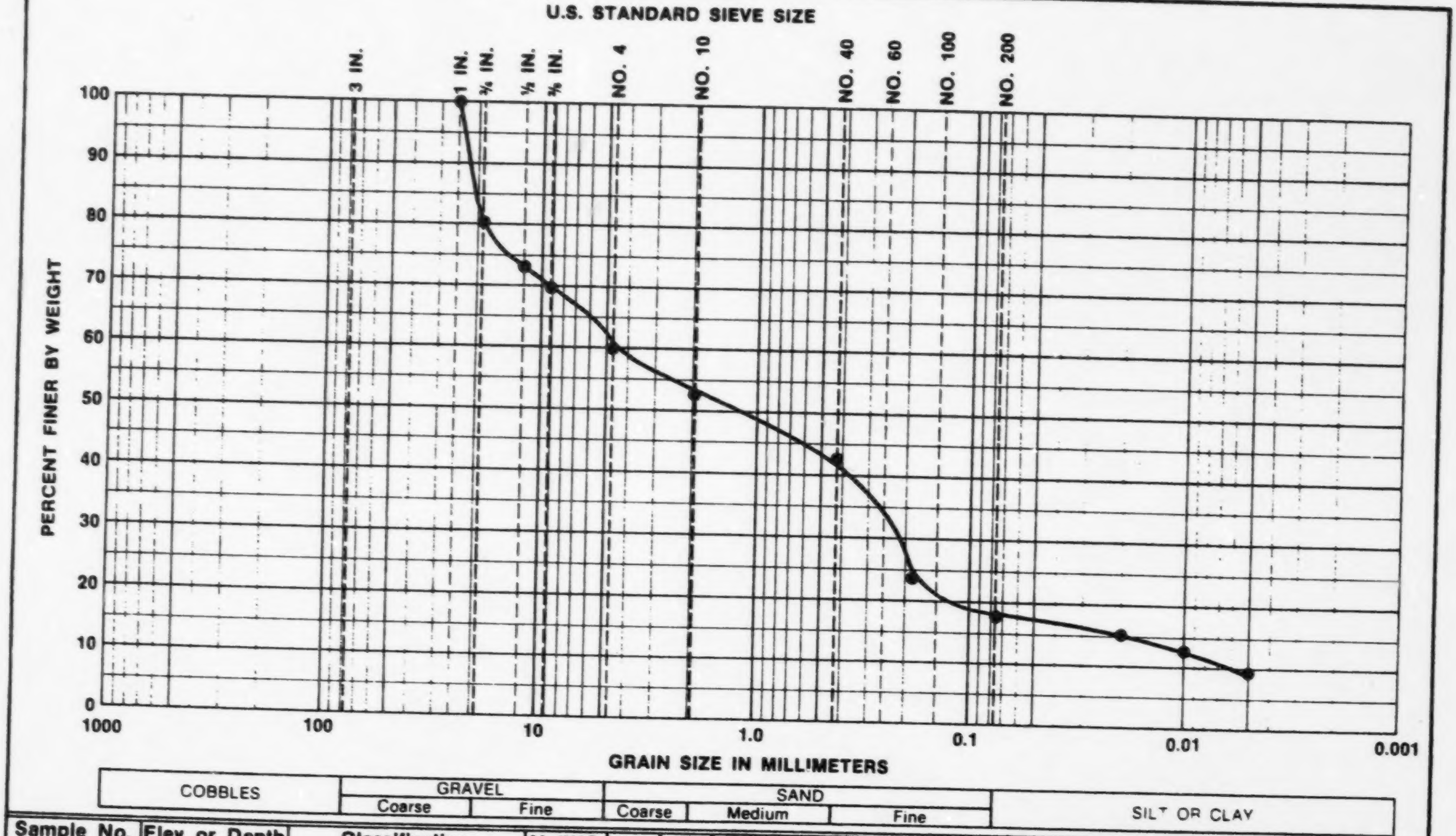
Figure B-5. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 2-6 | 7.62-8.08 | SM | 11.0 | 19 | NP | NP | |

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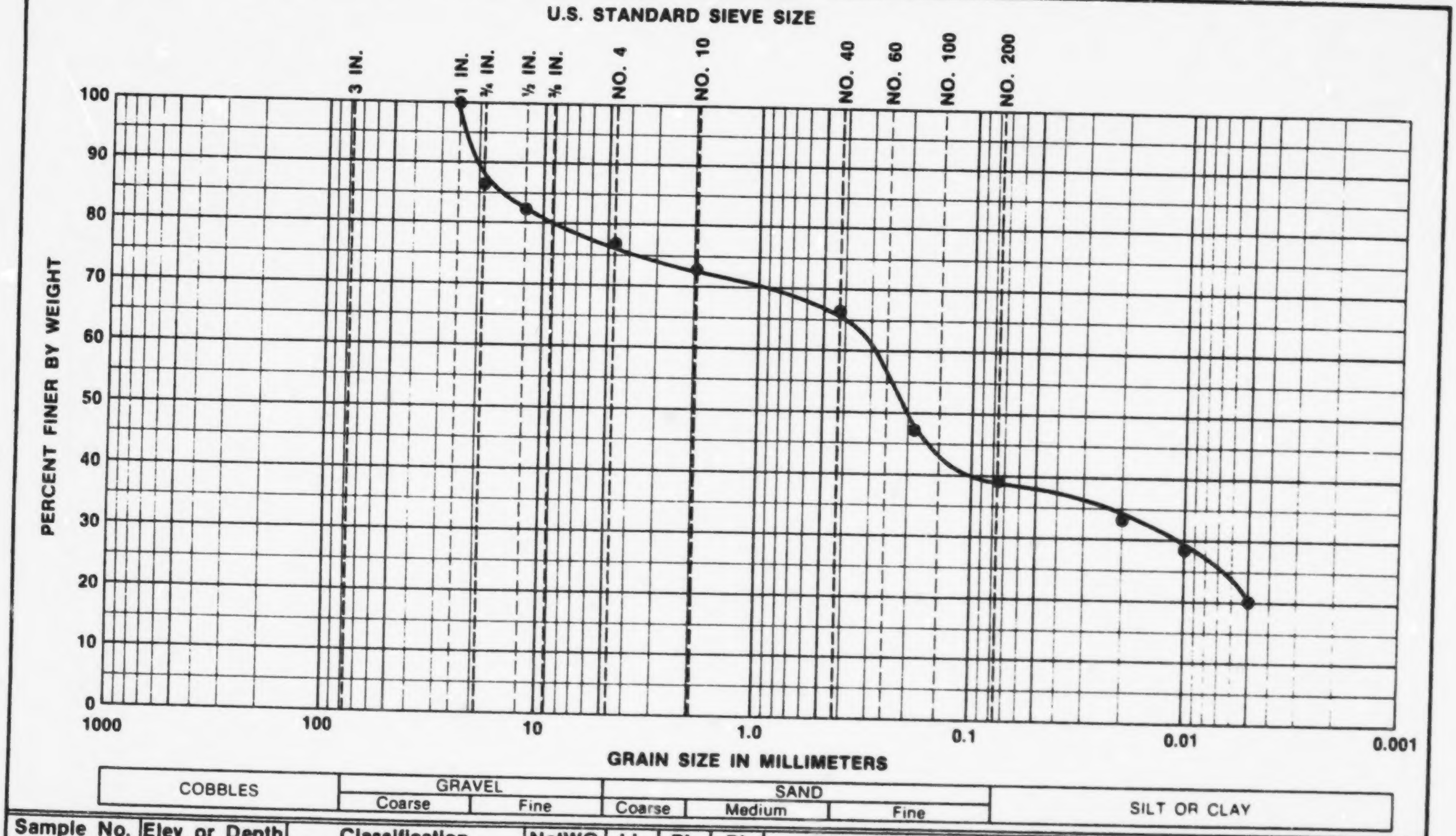
Figure B-6. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 2-8 | 10.67-10.82 | SM-SC | 17.1 | 24 | 17 | 7 | |

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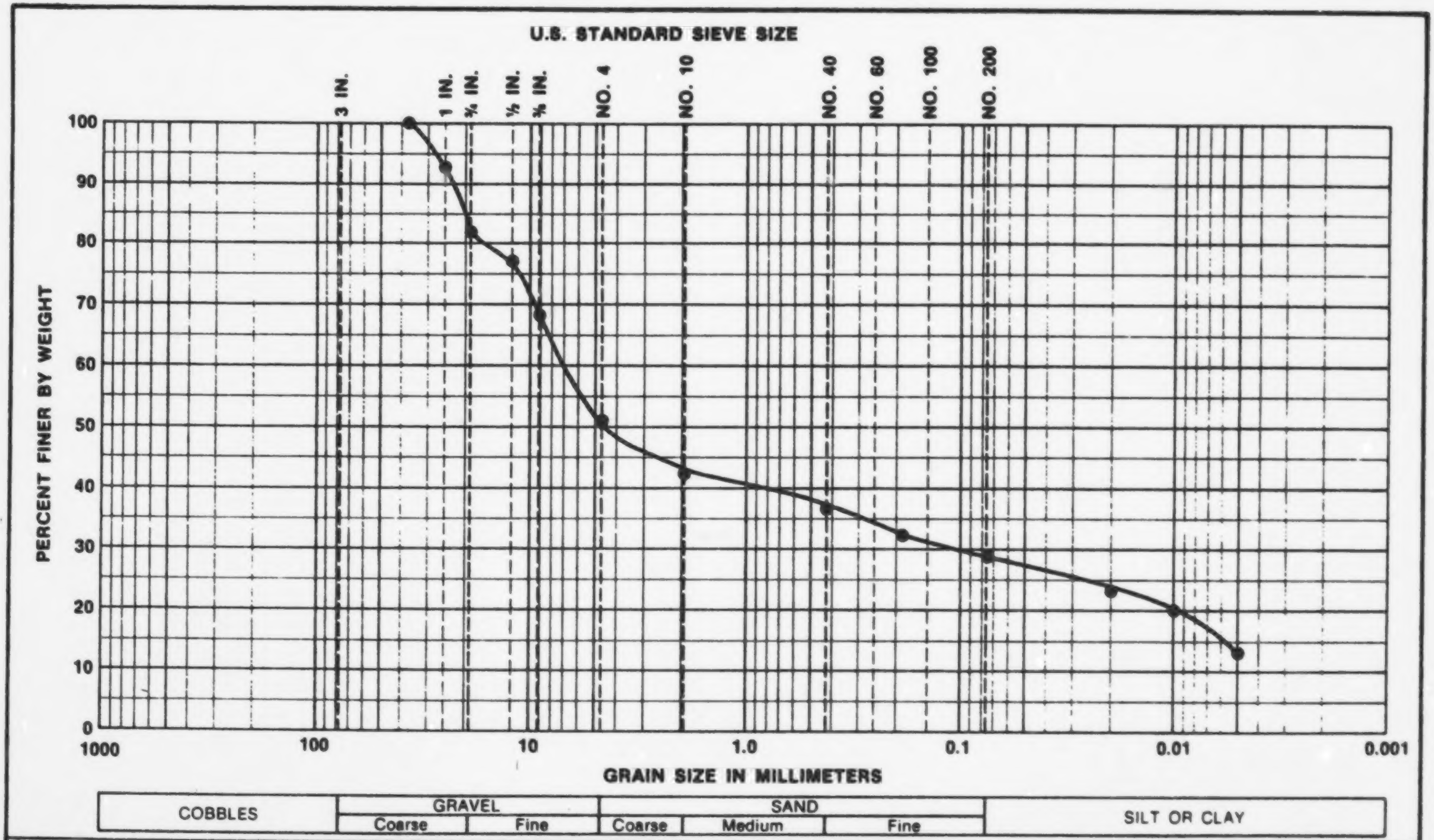
Figure B-7. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 2-9 | 12.19-12.65 | GC | 15.3 | 30 | 20 | 10 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

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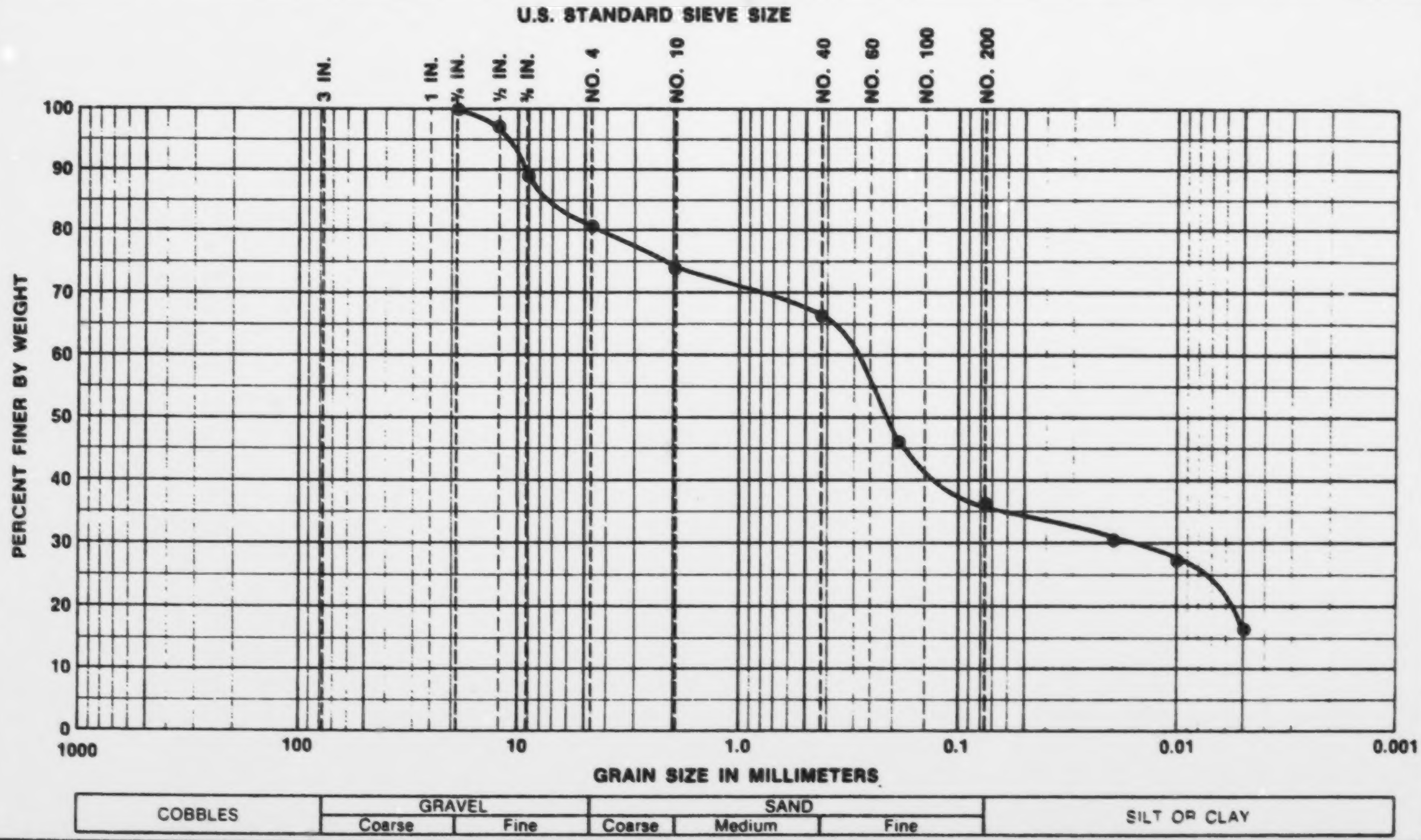
## GRADATION CURVES

Figure B-8. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 2-16 | 22.86-23.32 | SM | 11.8 | 19 | 17 | 2 | |

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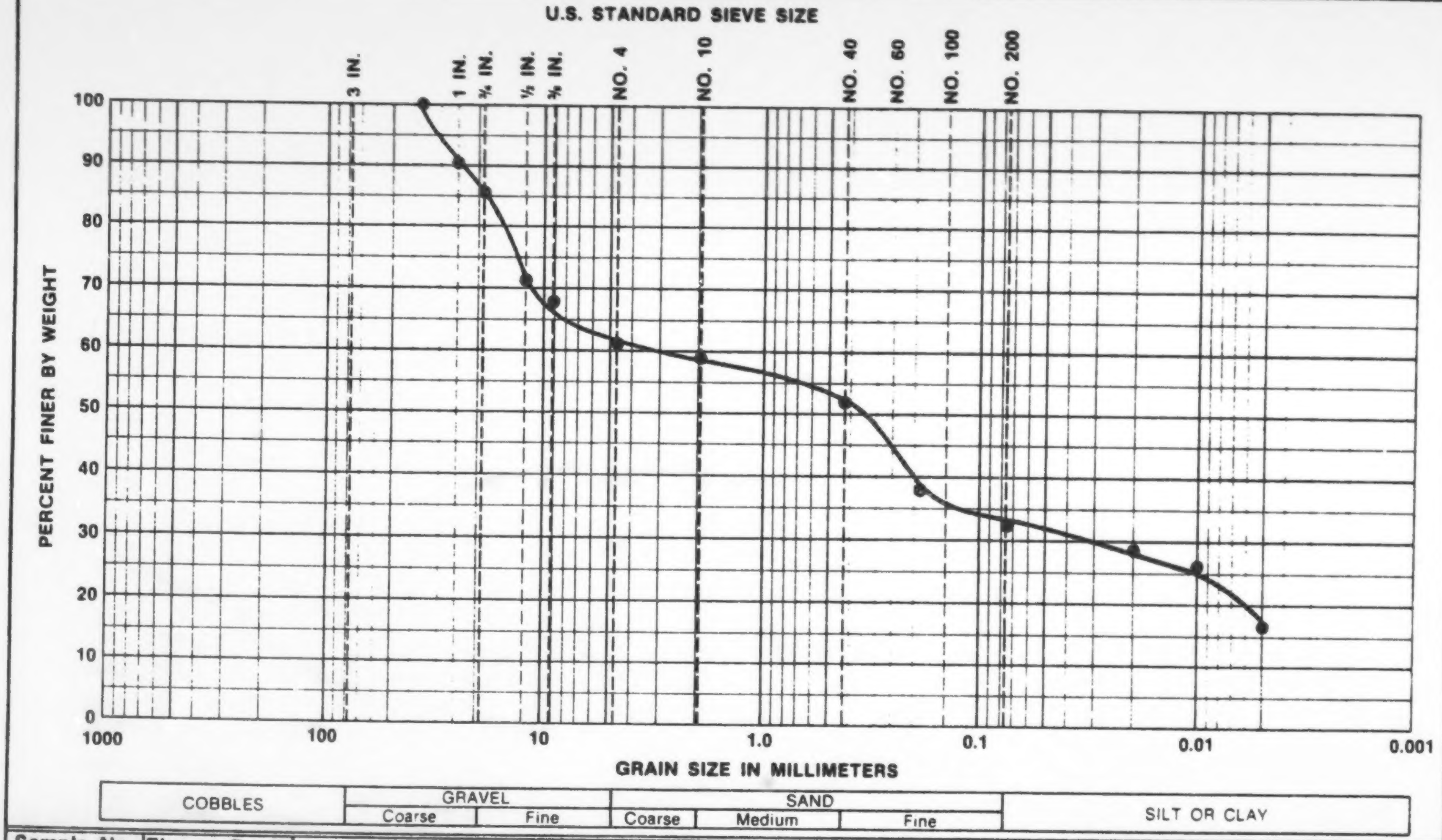
Figure B-9. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 3-4 | 4.57-5.03 | GM-GC | 12.2 | 23 | 17 | 6 | |

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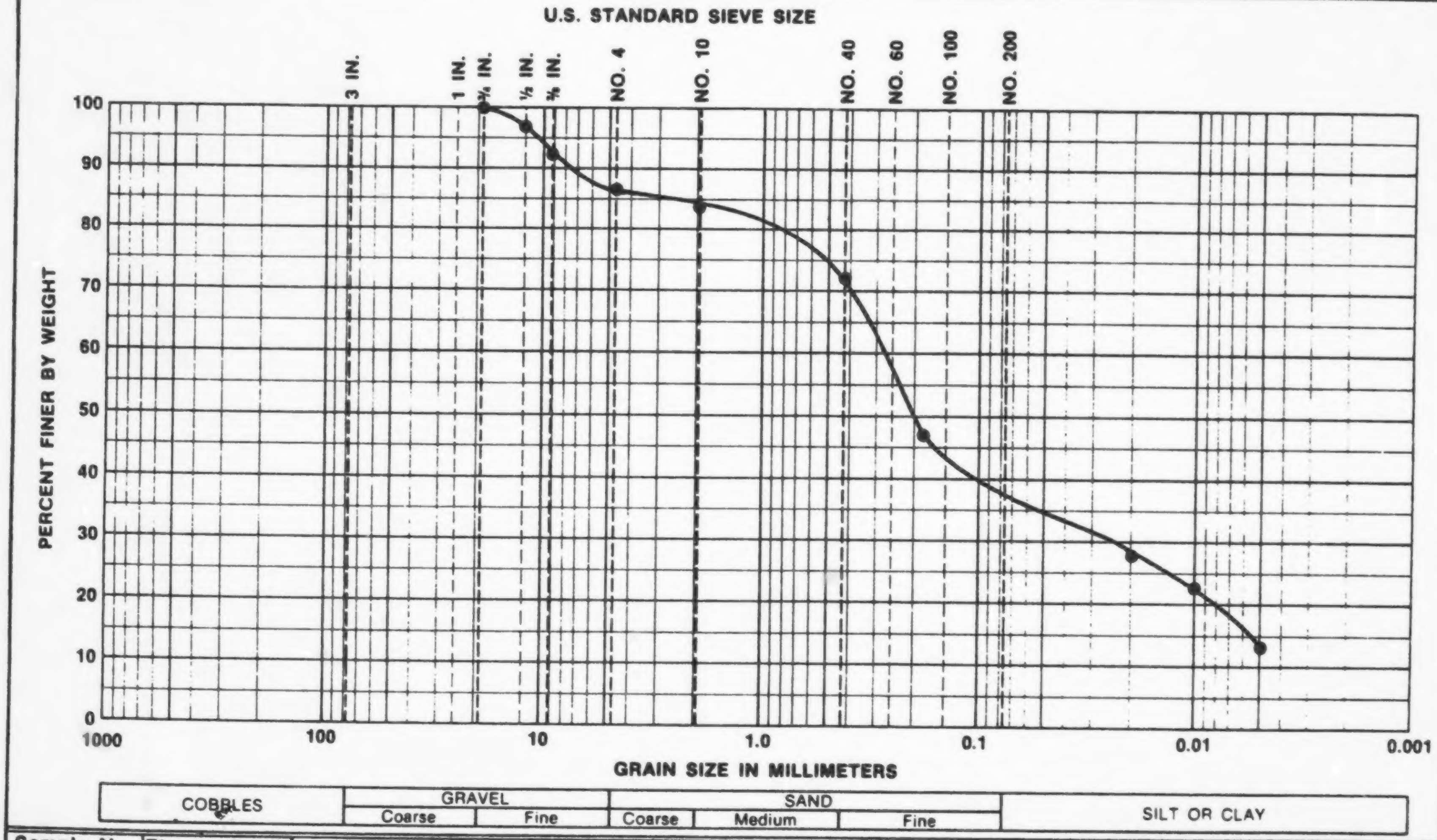
Figure B-10. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Sp 3-11 | 15.24-15.70 | SM | 8.7 | 18 | NP | NP | |

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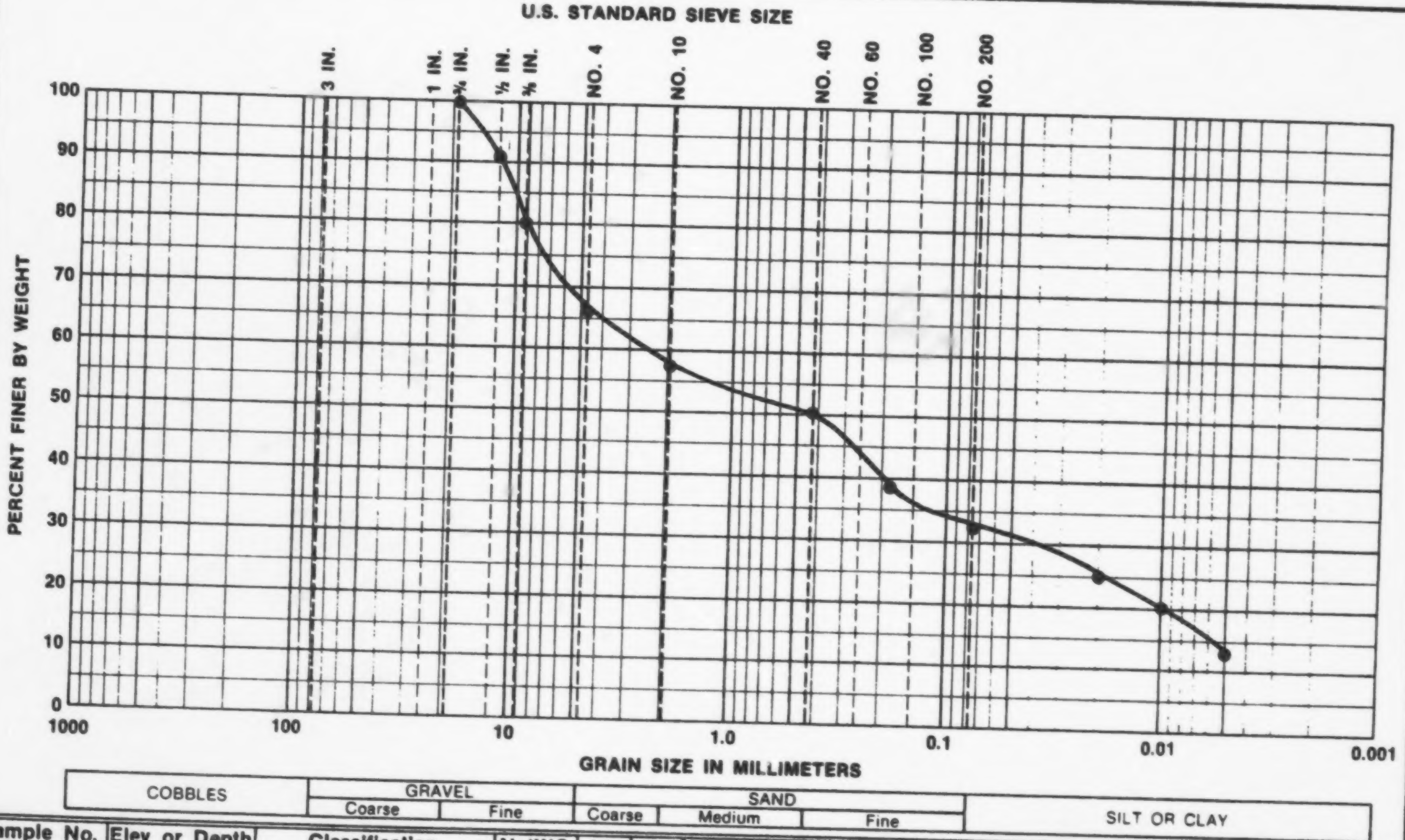
Figure B-11. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SpS1-0 | 0-.61 | GM-GC | 8.5 | 23 | 18 | 5 | |

**GRADATION CURVES**

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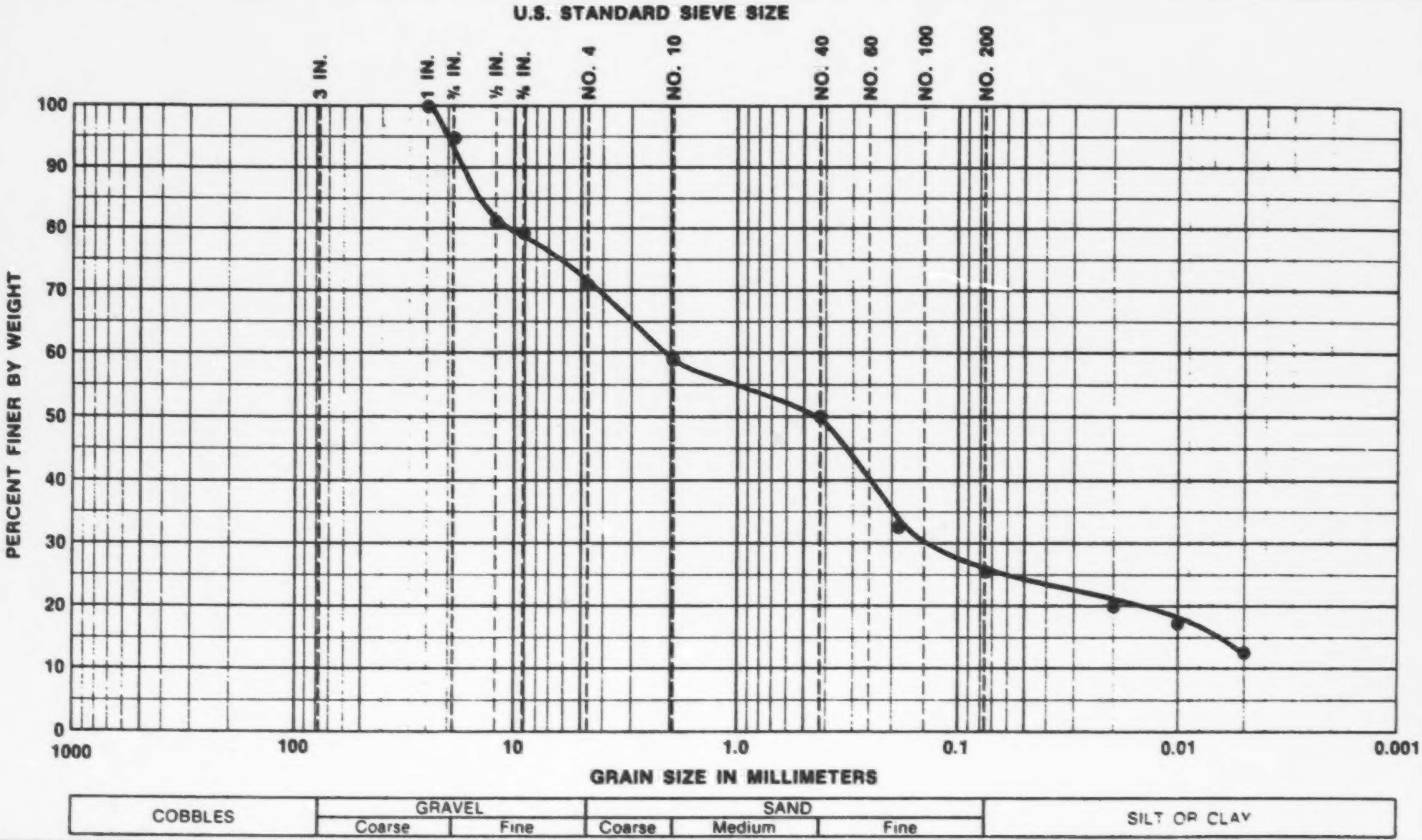
Figure B-12. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SpS1-10 | 3.05-3.66 | SM | 6.8 | 20 | 17 | 3 | |

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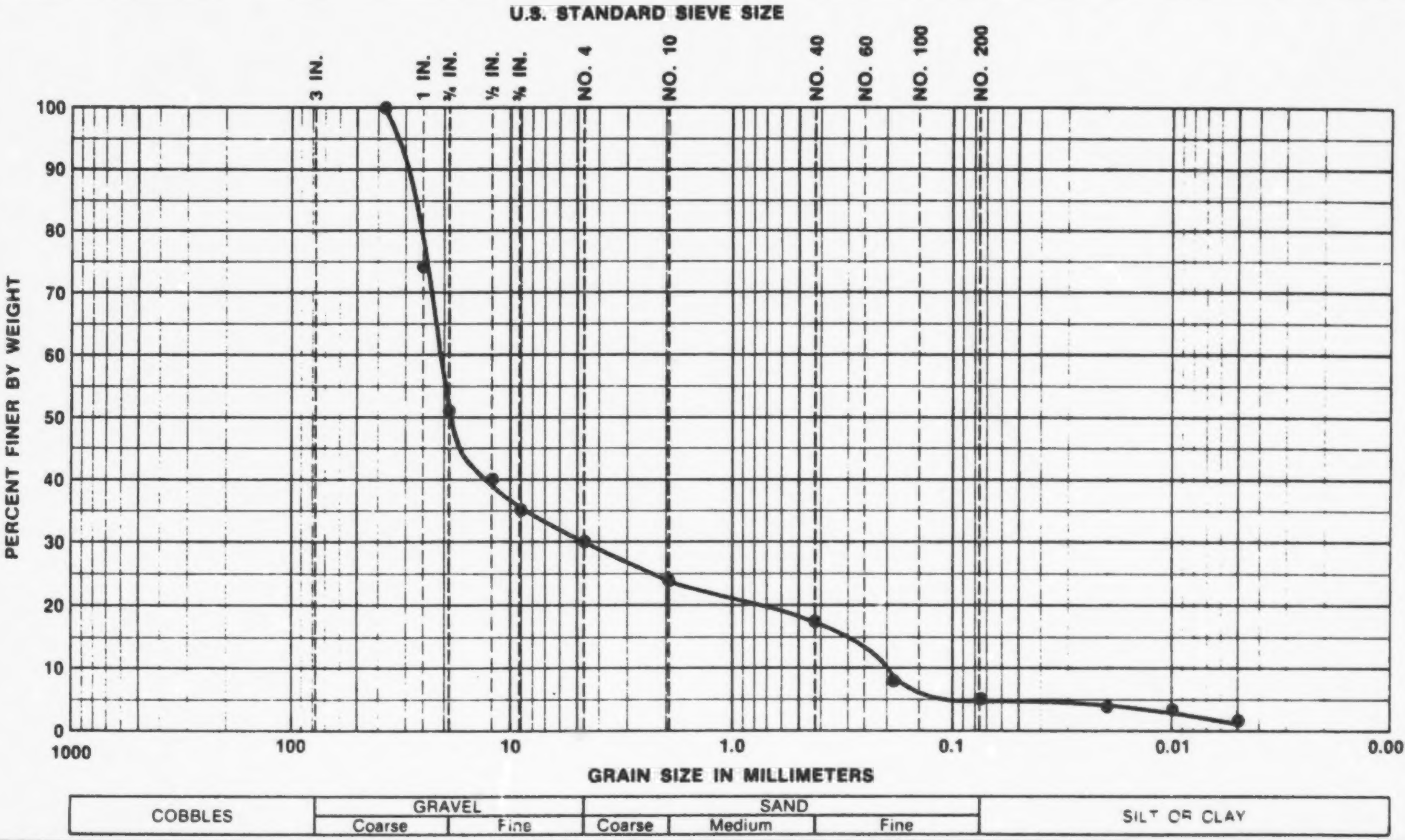
|---|---|---|
| 10/80 | DB | EML |

**GRADATION CURVES**

Figure B-13. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SpS1-20 | 6.1-6.86 | GM | 6.9 | NP | NP | NP | |

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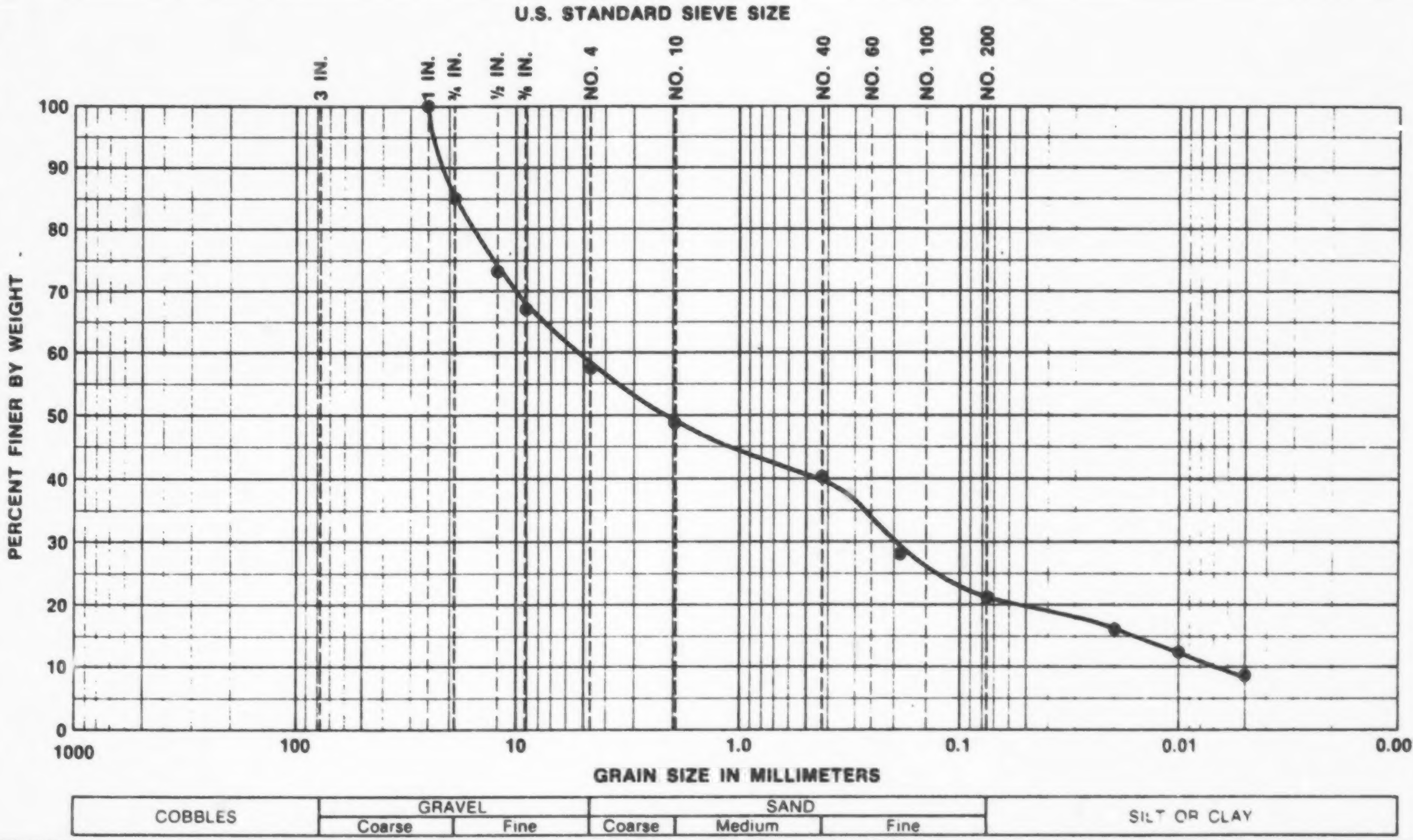
Figure B-14. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SPS1-30 | 9.14-9.63 | GM-GC | 9.8 | 21 | 16 | 5 | |

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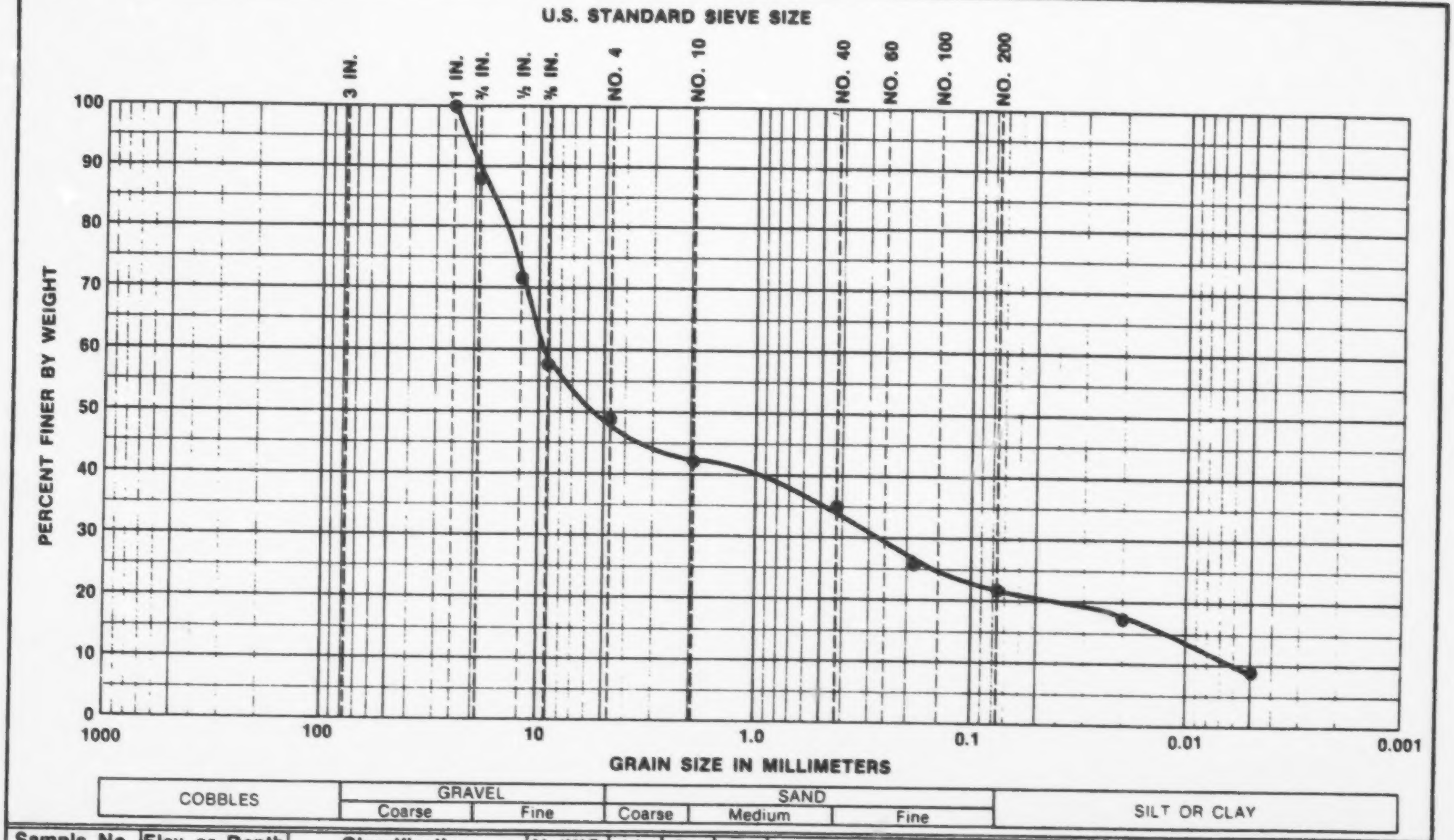
Figure B-15. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SpS1-60 | 18.29-18.90 | GM-GC | 4.2 | 23 | 16 | 7 | |

## GRADATION CURVES

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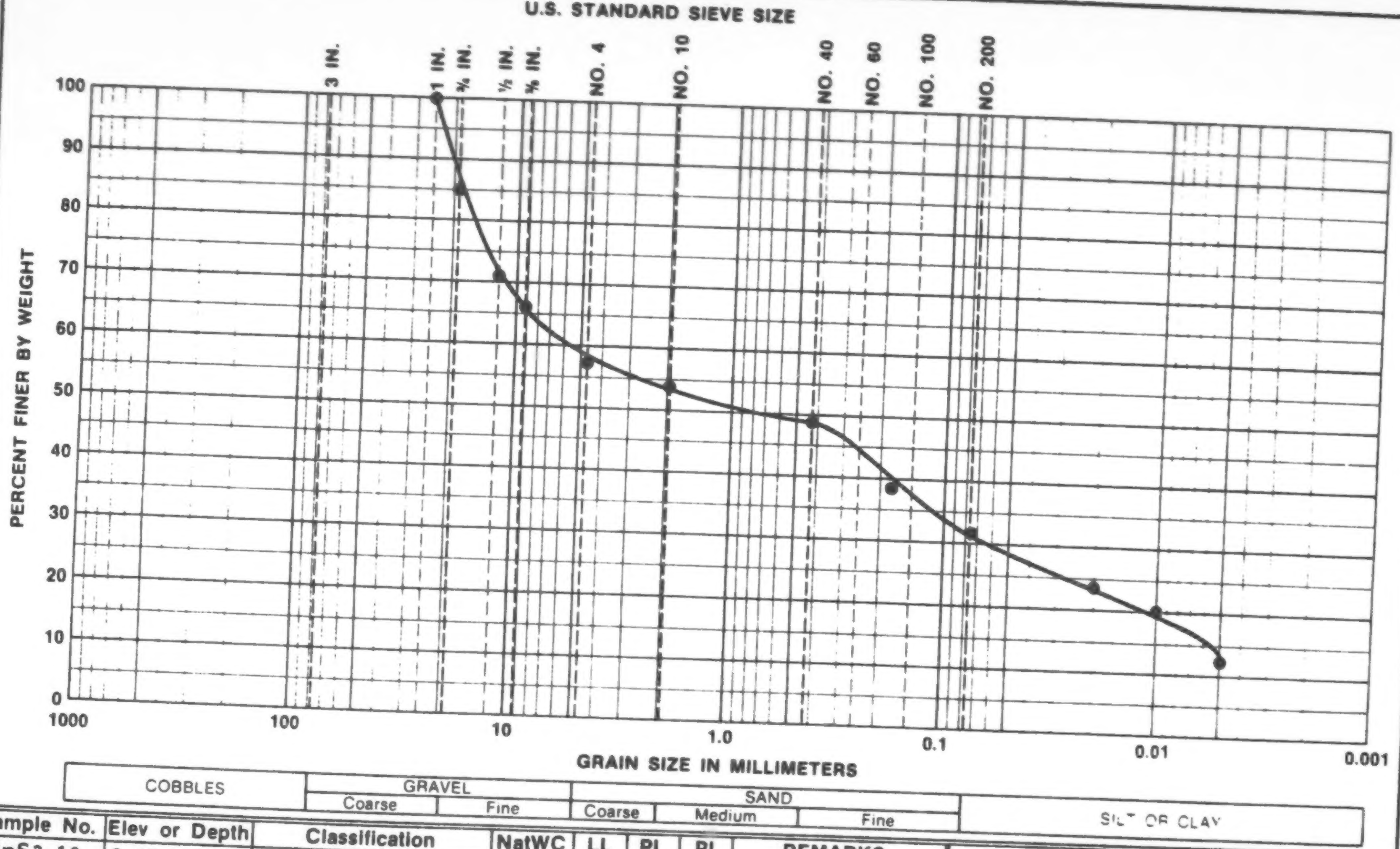
Figure B-16. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SpS2-10 | 3.05-3.20 | GM-GC | 12.8 | 22 | 17 | 5 | |

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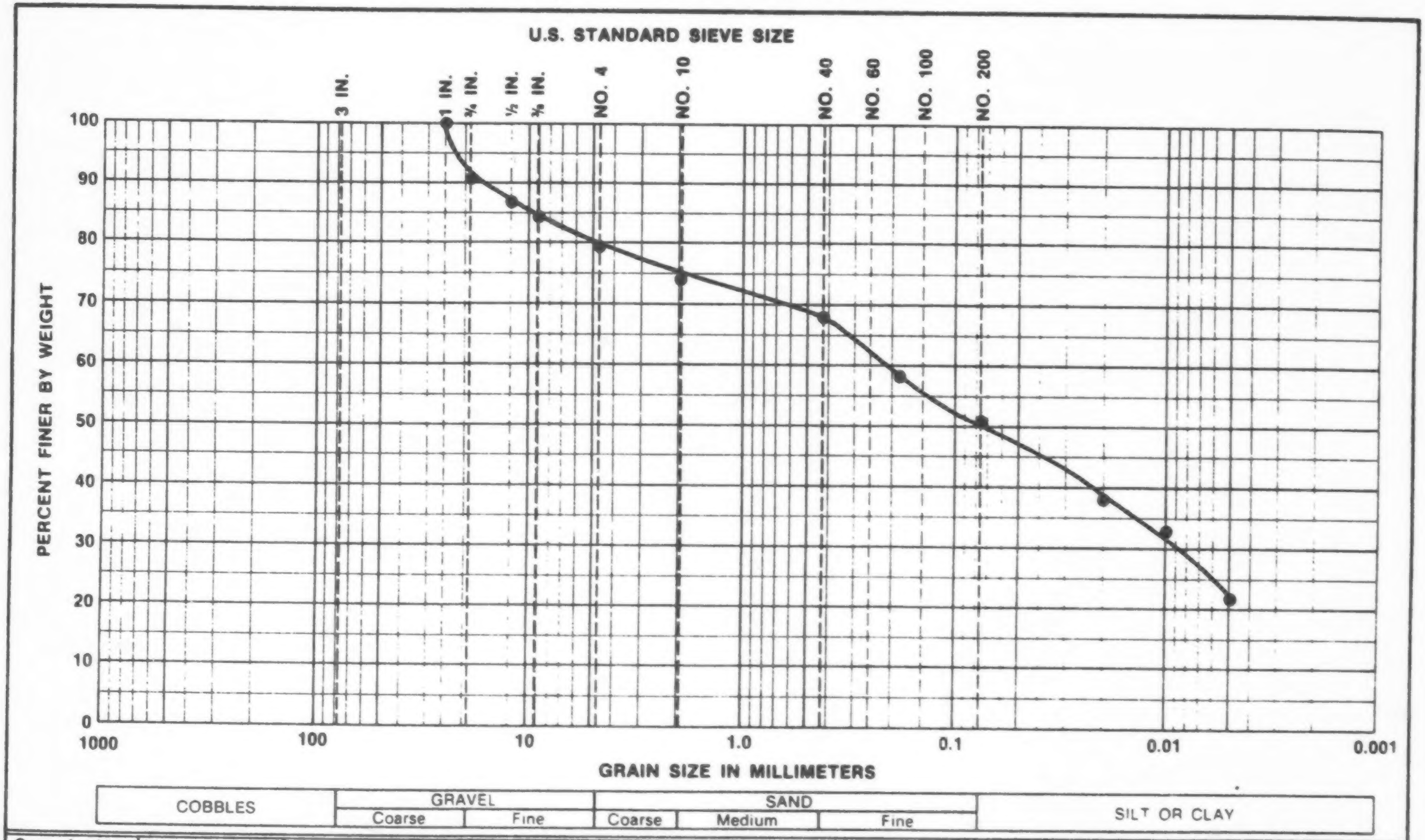
Figure B-17. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SpS3-5 | 1.52-2.13 | CL | 12.3 | 27 | 19 | 8 | |

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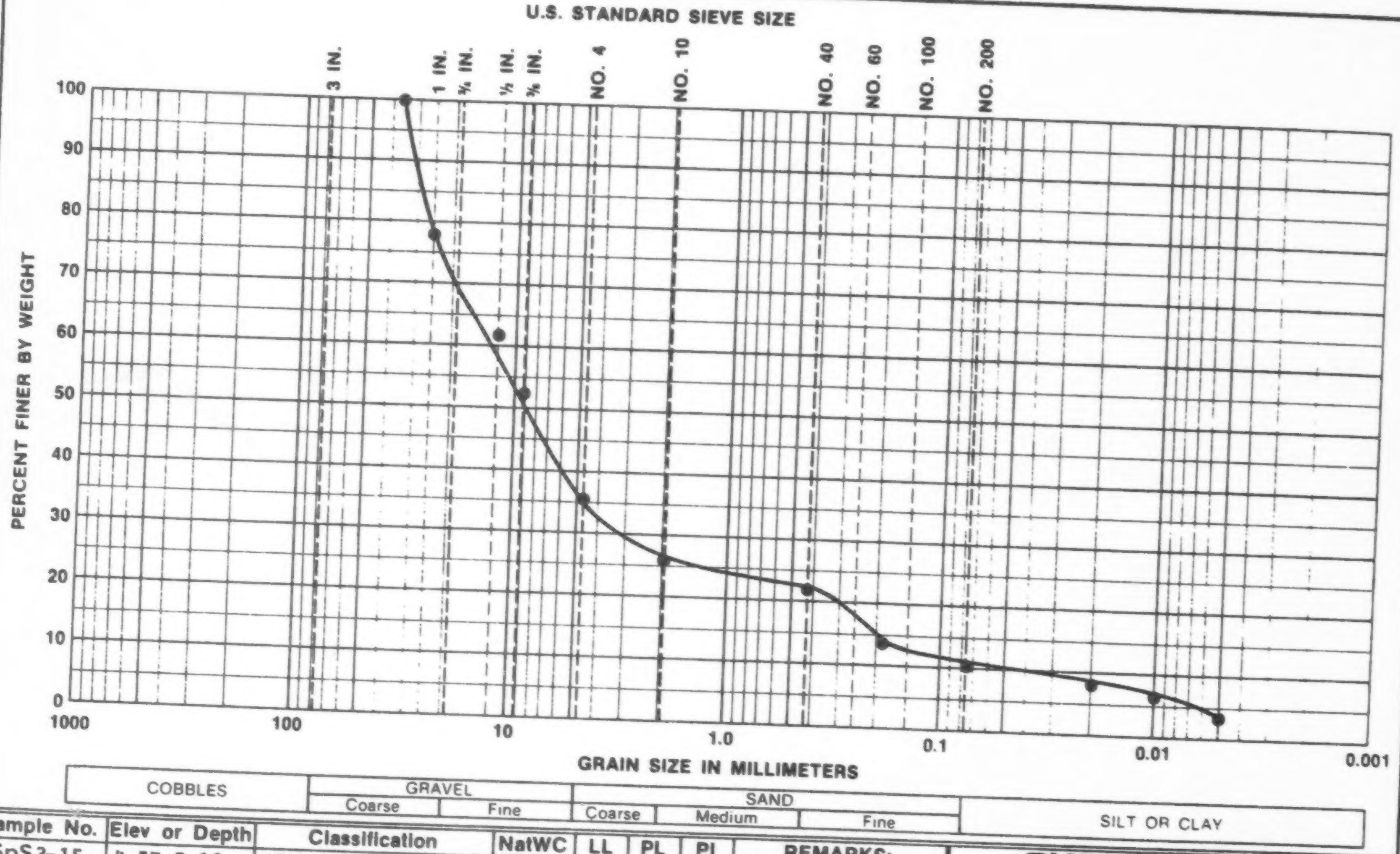
Figure B-18. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| SpS3-15 | 4.57-5.18 | GM-GC | 9.4 | NP | NP | NP | |

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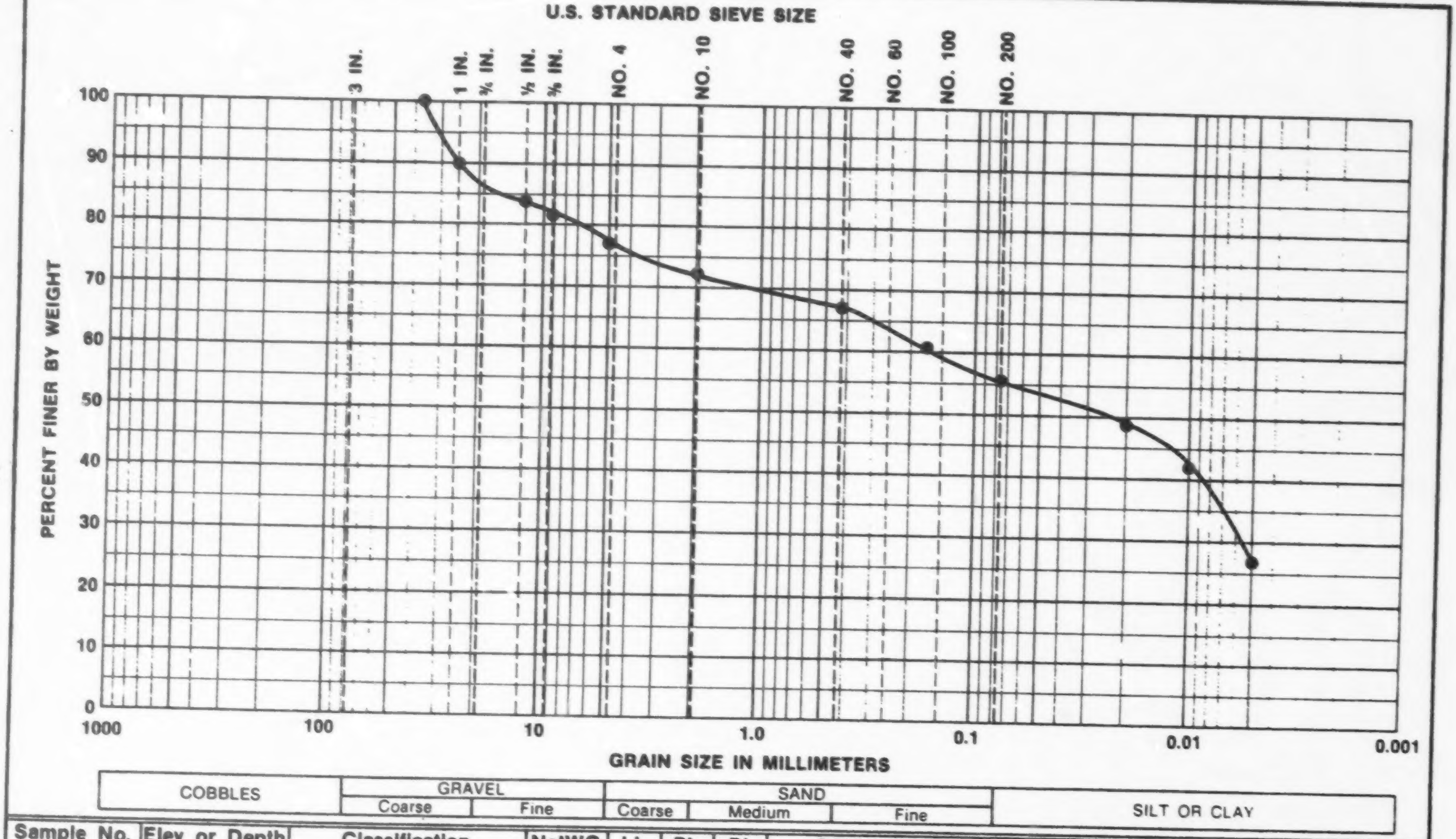
Figure B-19. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B1-2 | .61-1.07 | CL-ML | 21.6 | 30 | 23 | 7 | |

## GRADATION CURVES

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Location: Perry County, Kentucky
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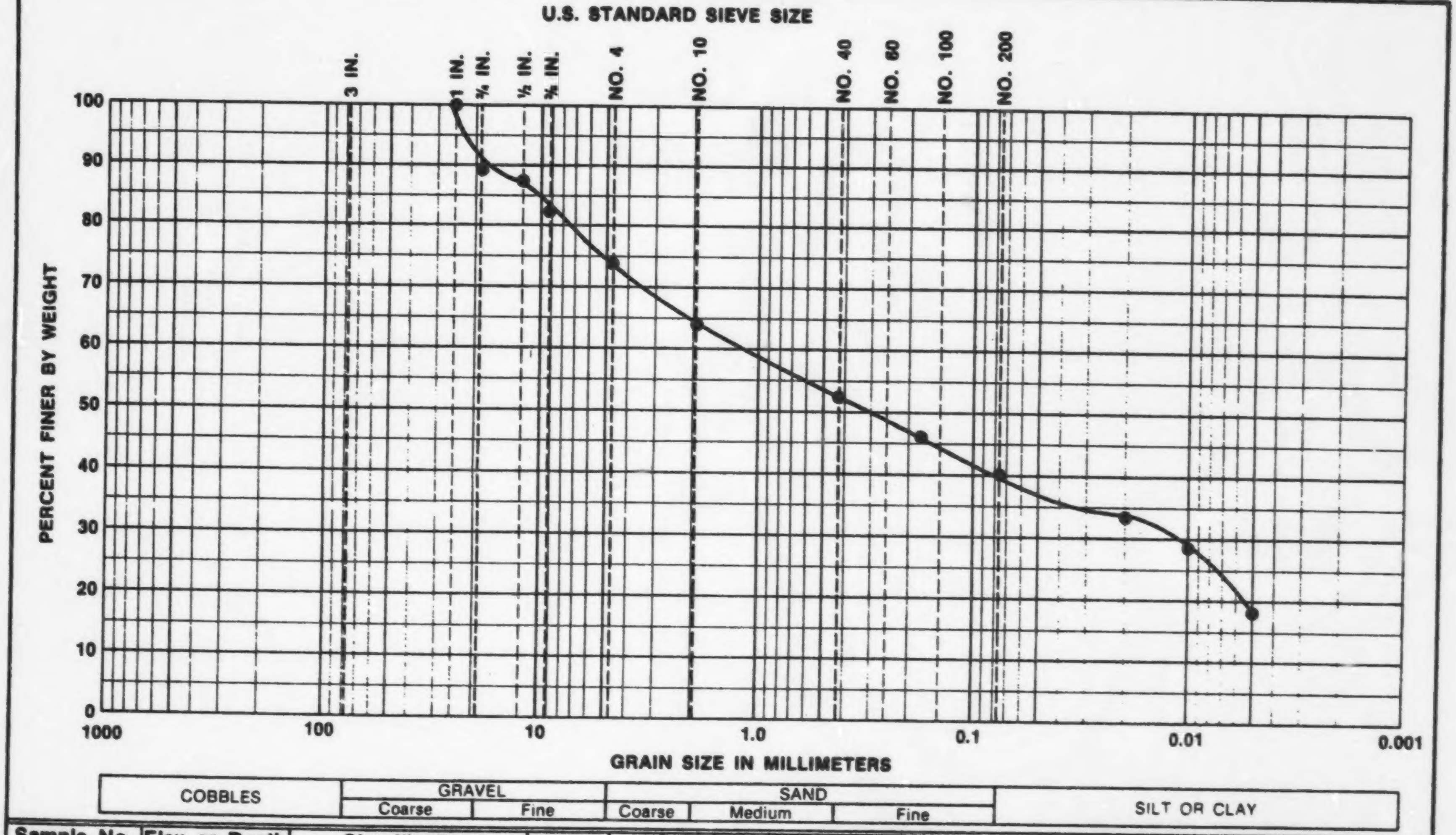
Figure B-20. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B2-1 | 0-.46 | SM-SC | 16.7 | 28 | 22 | 6 | |

**GRADATION CURVES**

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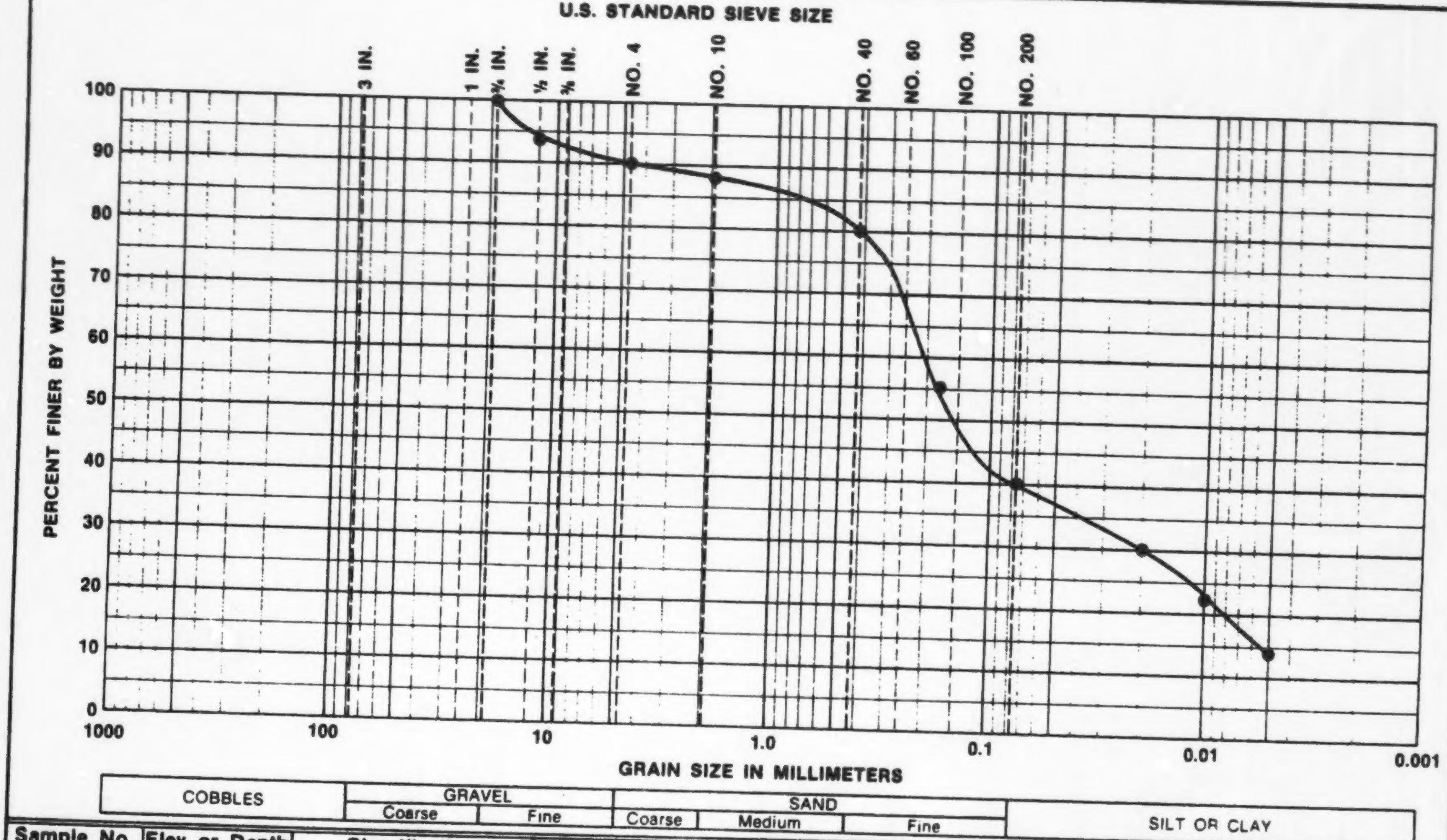
Figure B-21. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B2-11 | 11.73-12.19 | SW | 13.6 | 19 | 17 | 2 | |

**GRADATION CURVES**

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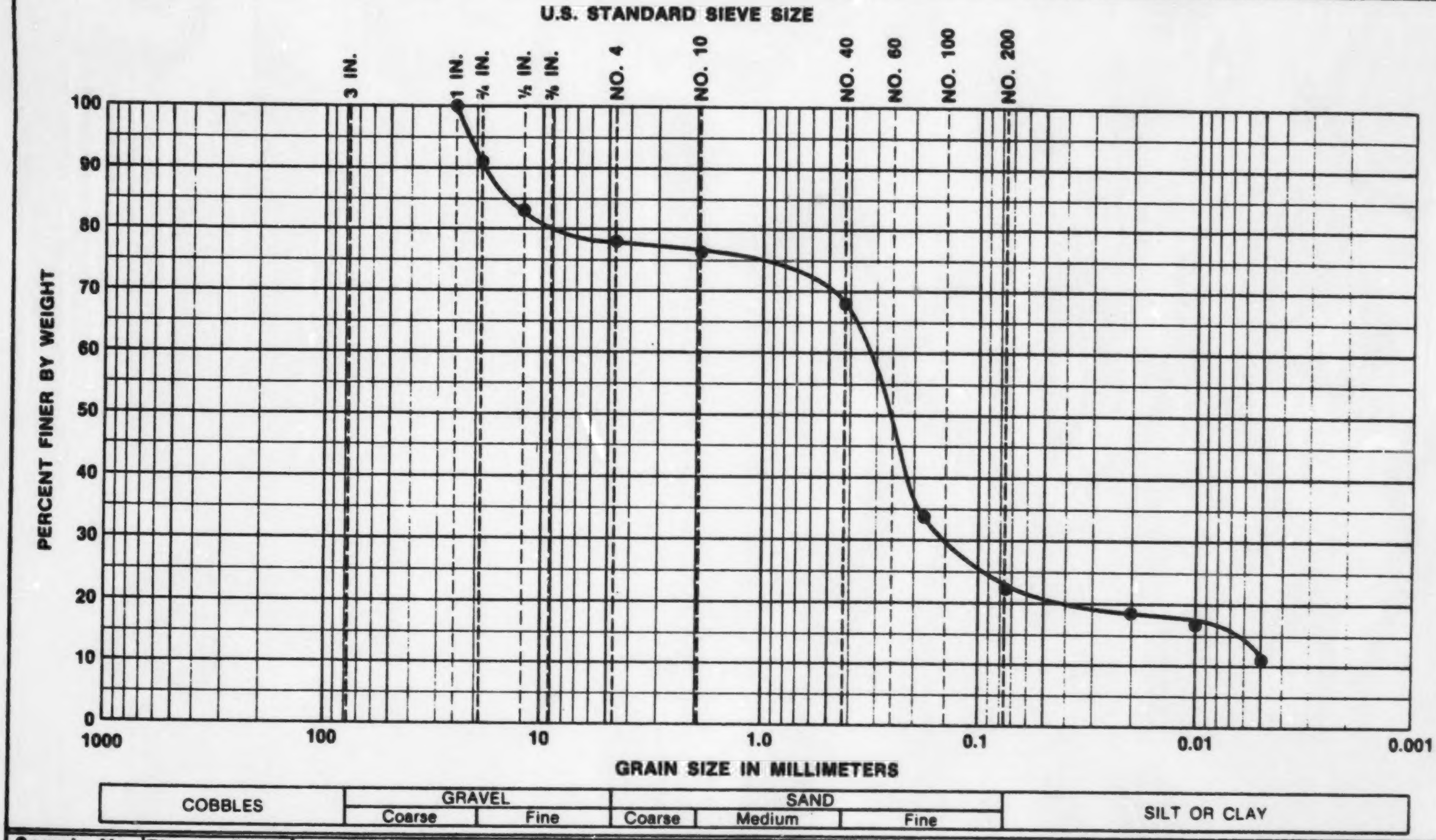
Figure B-22. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B2-12 | 13.26-13.72 | SM | 14.3 | 16 | NP | NP | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**GRADATION CURVES**

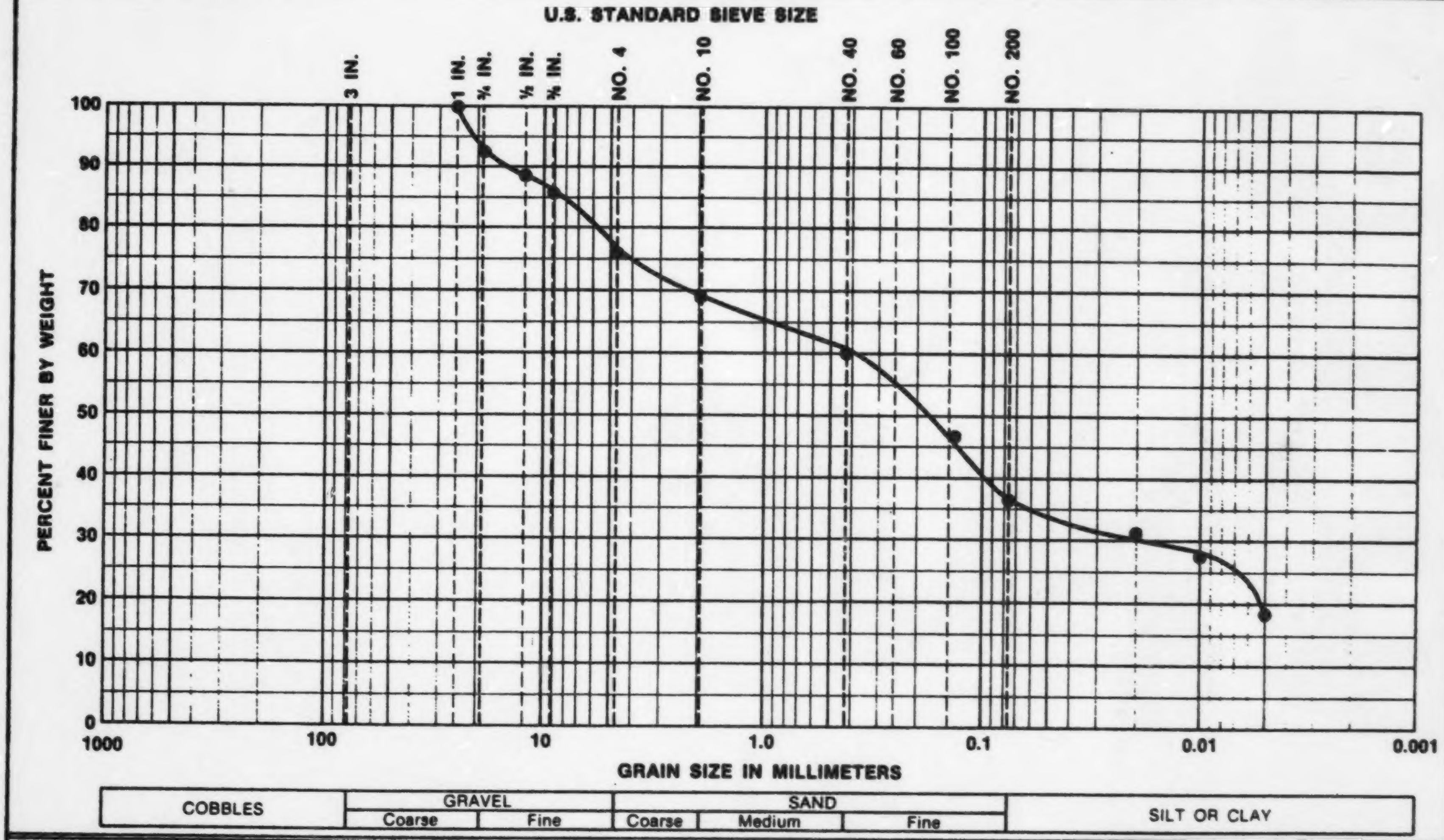
**SKELLY AND LOY**
**Engineers-Consultants**
**Harrisburg, Pennsylvania**

Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

| Date | 9/80 | Made By | DB | Chkd By | EML |
|---|---|---|---|---|---|

Figure B-23. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B3-5 | 2.59-3.05 | SM-SC | 17.6 | 22 | 17 | 5 | |

**GRADATION CURVES**

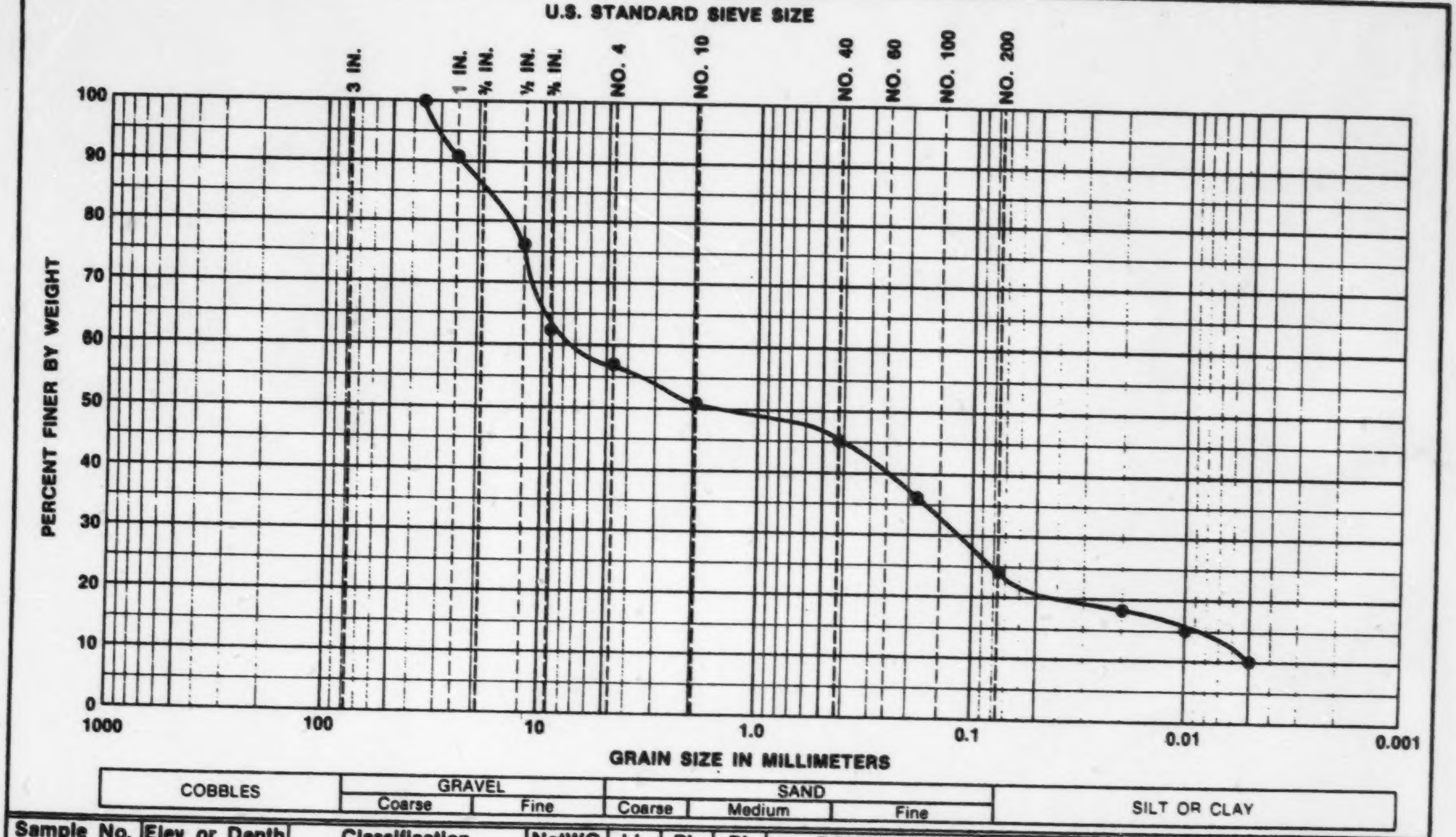
**SKELLY AND LOY**
Engineers-Consultants
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

| | | | |
|---|---|---|---|
| Date 9/80 | Made By DB | Chkd By EML | |

Figure B-24. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B3-7 | 5.64-6.1 | GM | 15.7 | 21 | NP | NP | |

## GRADATION CURVES

**SKELLY AND LOY**
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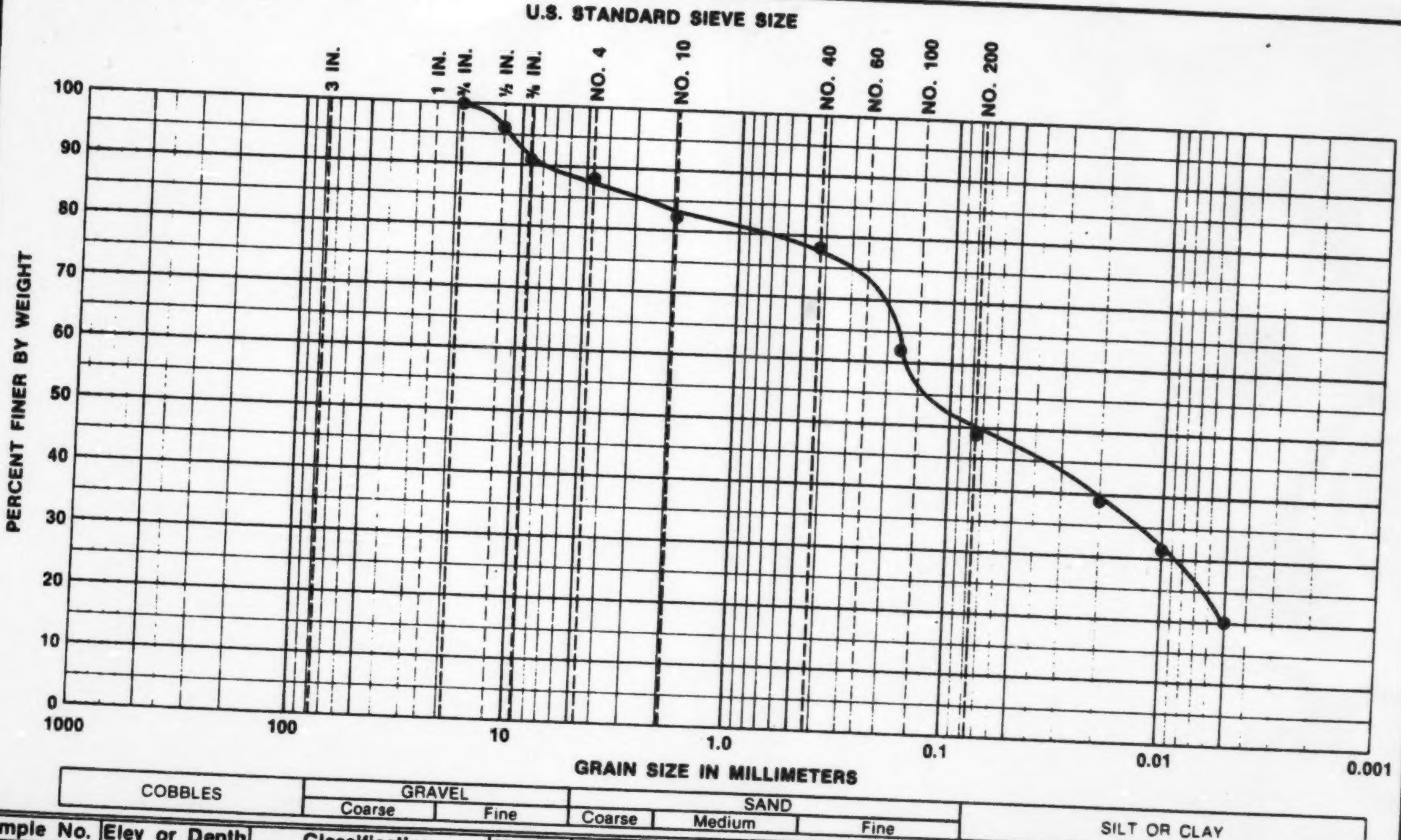
**Harrisburg, Pennsylvania**

Project Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

Figure B-25. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B3-16 | 23.92-24.38 | SM-SC | 16.8 | 24 | 19 | 5 | |

**SKELLY AND LOY**
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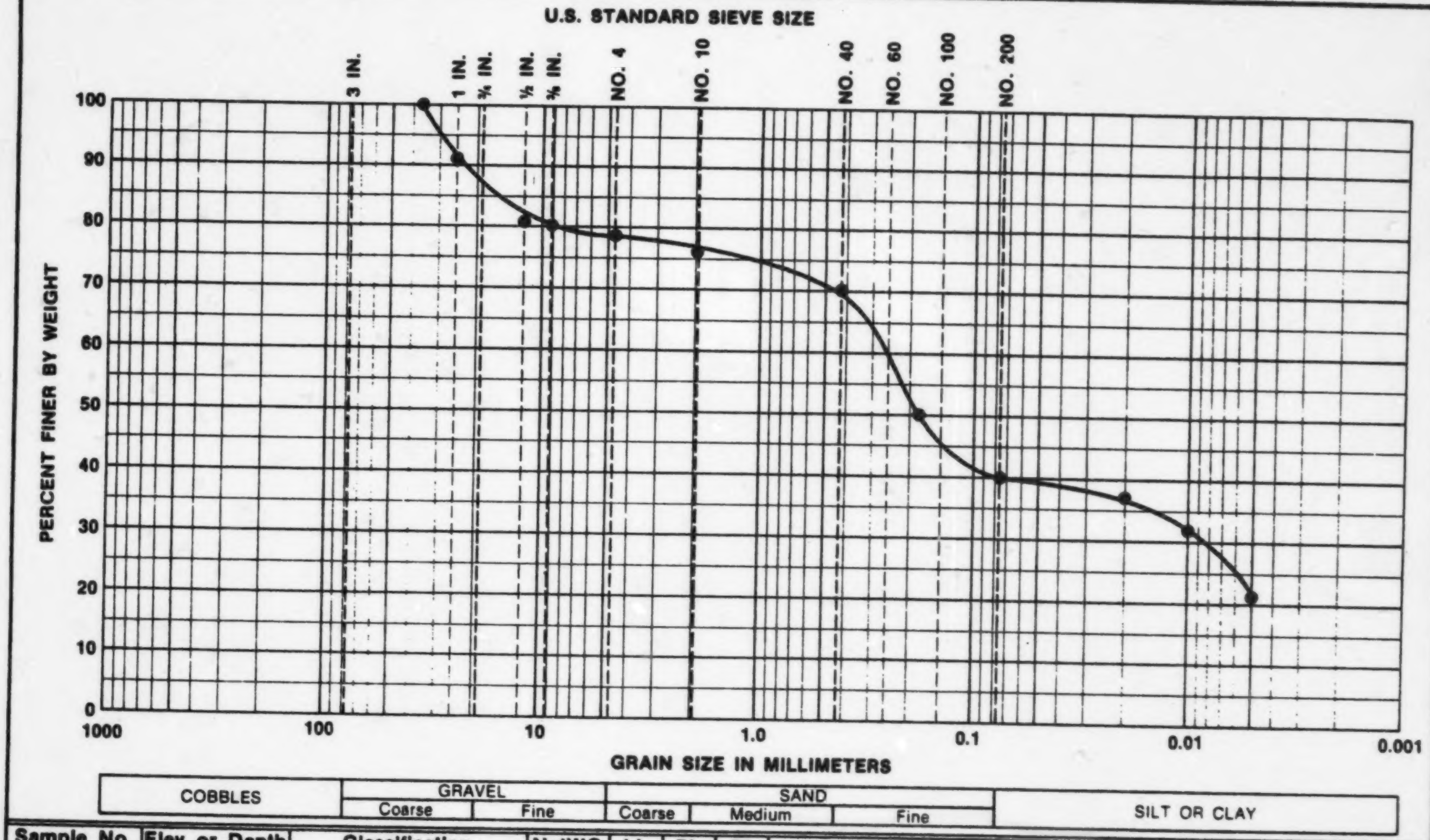
Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

Date 9/80 Made By DB Chkd By EML

## GRADATION CURVES

Figure B-26. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B4-1 | .61-1.07 | SM-SC | 13.5 | 22 | 16 | 7 | |

## GRADATION CURVES

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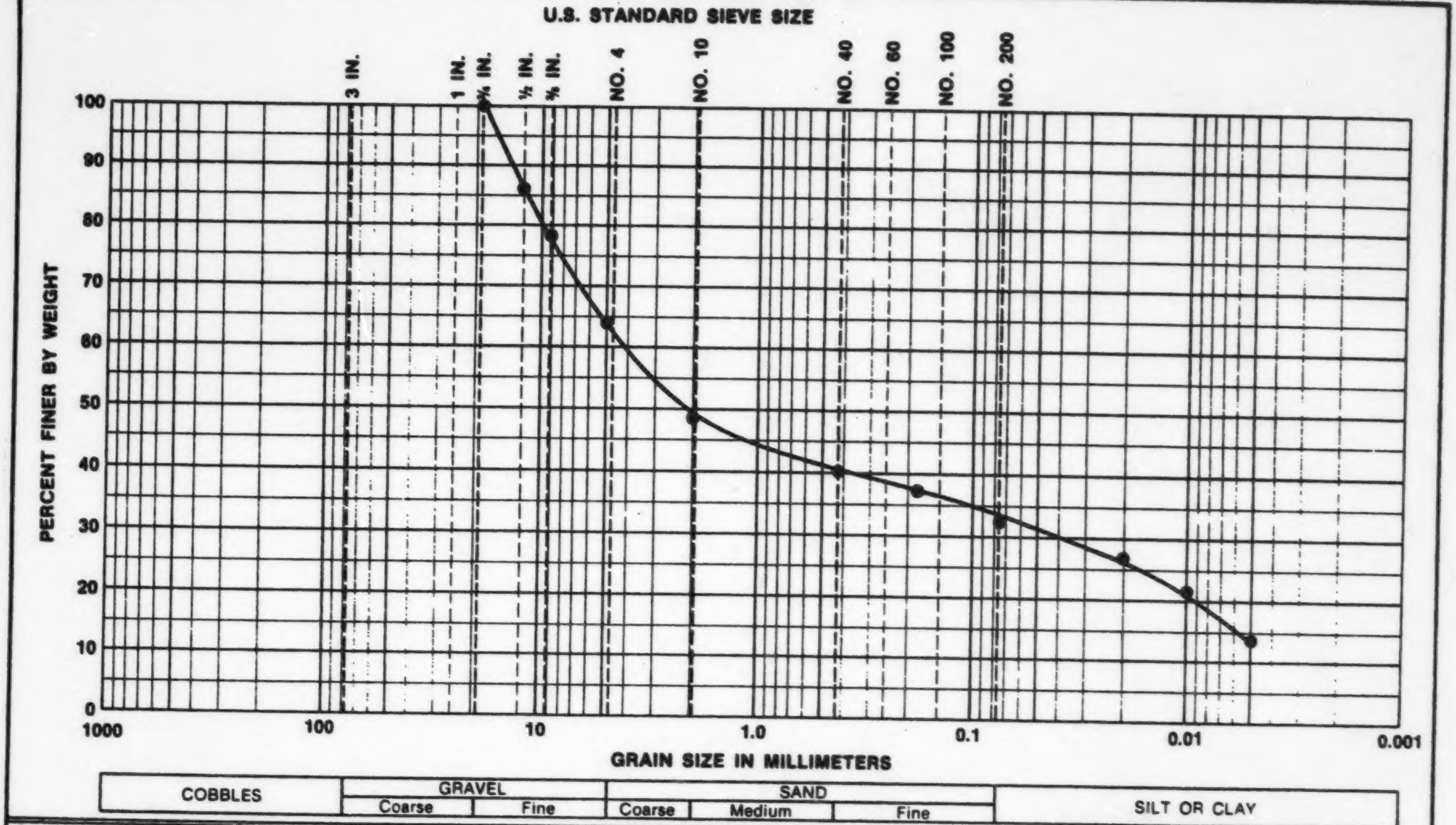
**Harrisburg, Pennsylvania**

Project: Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

Figure B-27. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B4-4 | 4.11-4.57 | GM-GC | 12.9 | 27 | 20 | 7 | |

**GRADATION CURVES**

**SKELLY AND LOY**
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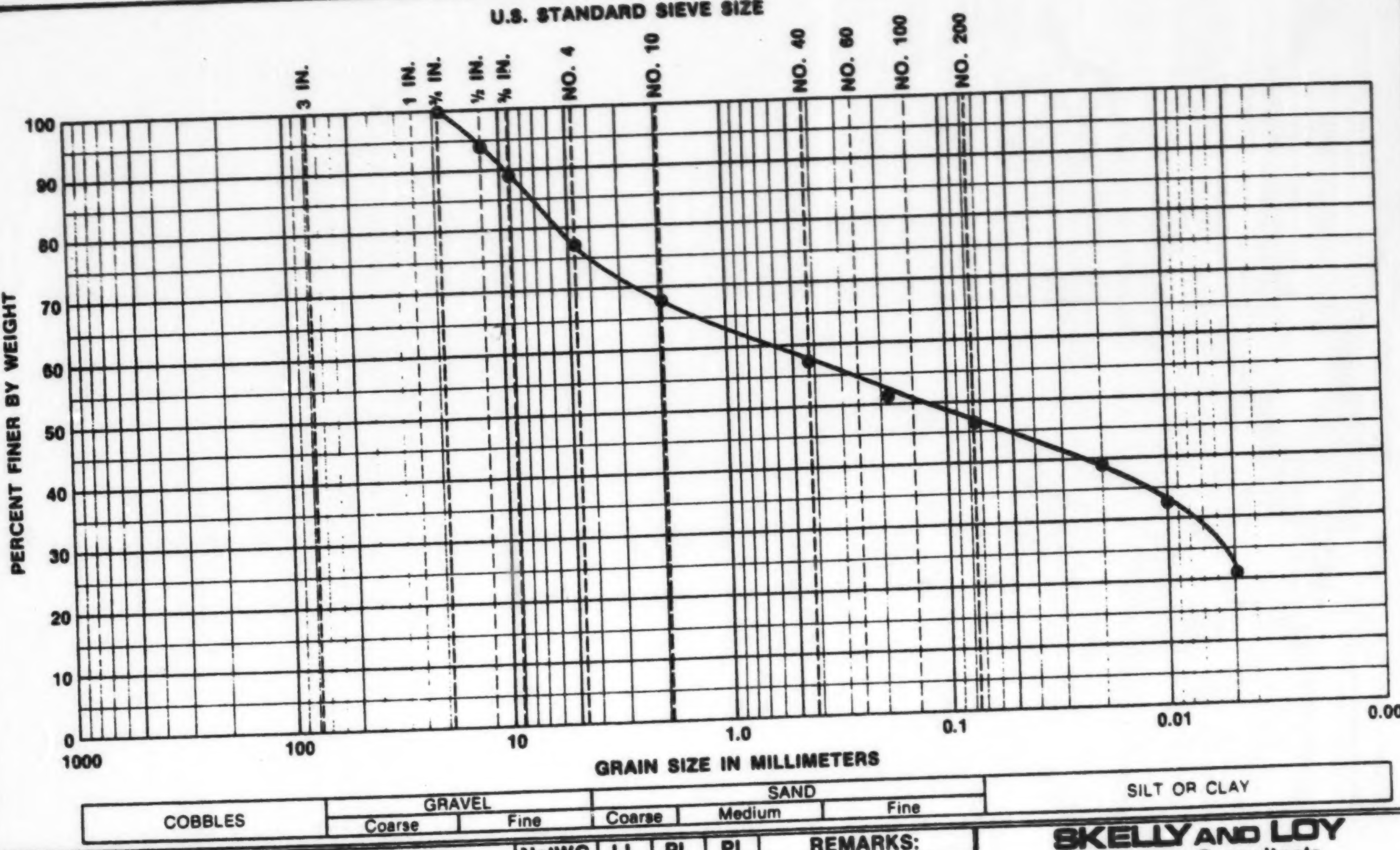
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

Date 9/80 Made By DB Chkd By EML

Figure B-28. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| B4-6 | 7.16-7.62 | SM-SC | 16.1 | 29 | 22 | 7 | |

**GRADATION CURVES**

**SKELLY AND LOY**
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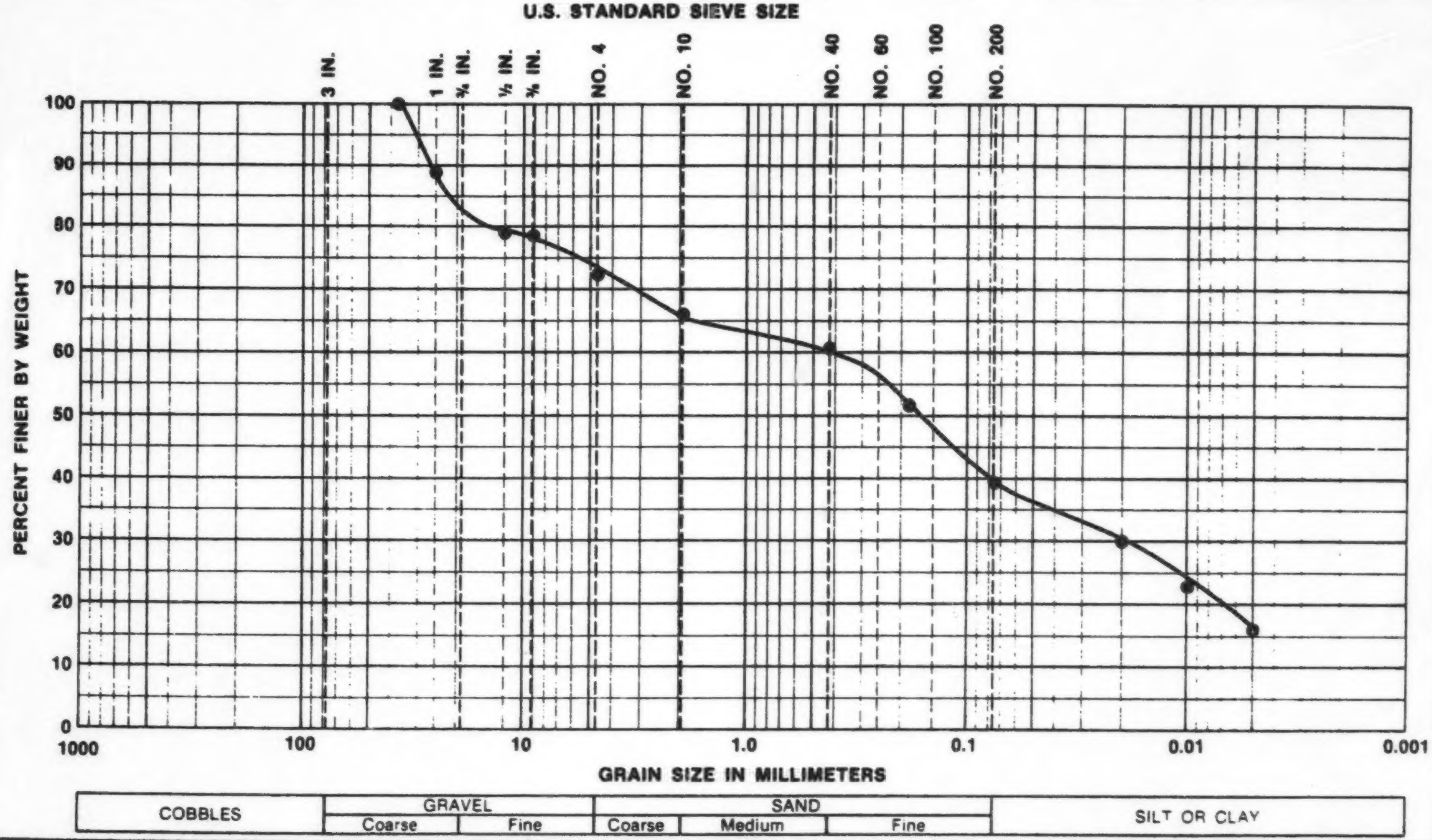
**Harrisburg, Pennsylvania**

Project: Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

Figure B-29. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu1-2 | 1.07-1.52 | GM-GC | 17.6 | 23 | 19 | 4 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**GRADATION CURVES**

**SKELLY AND LOY**
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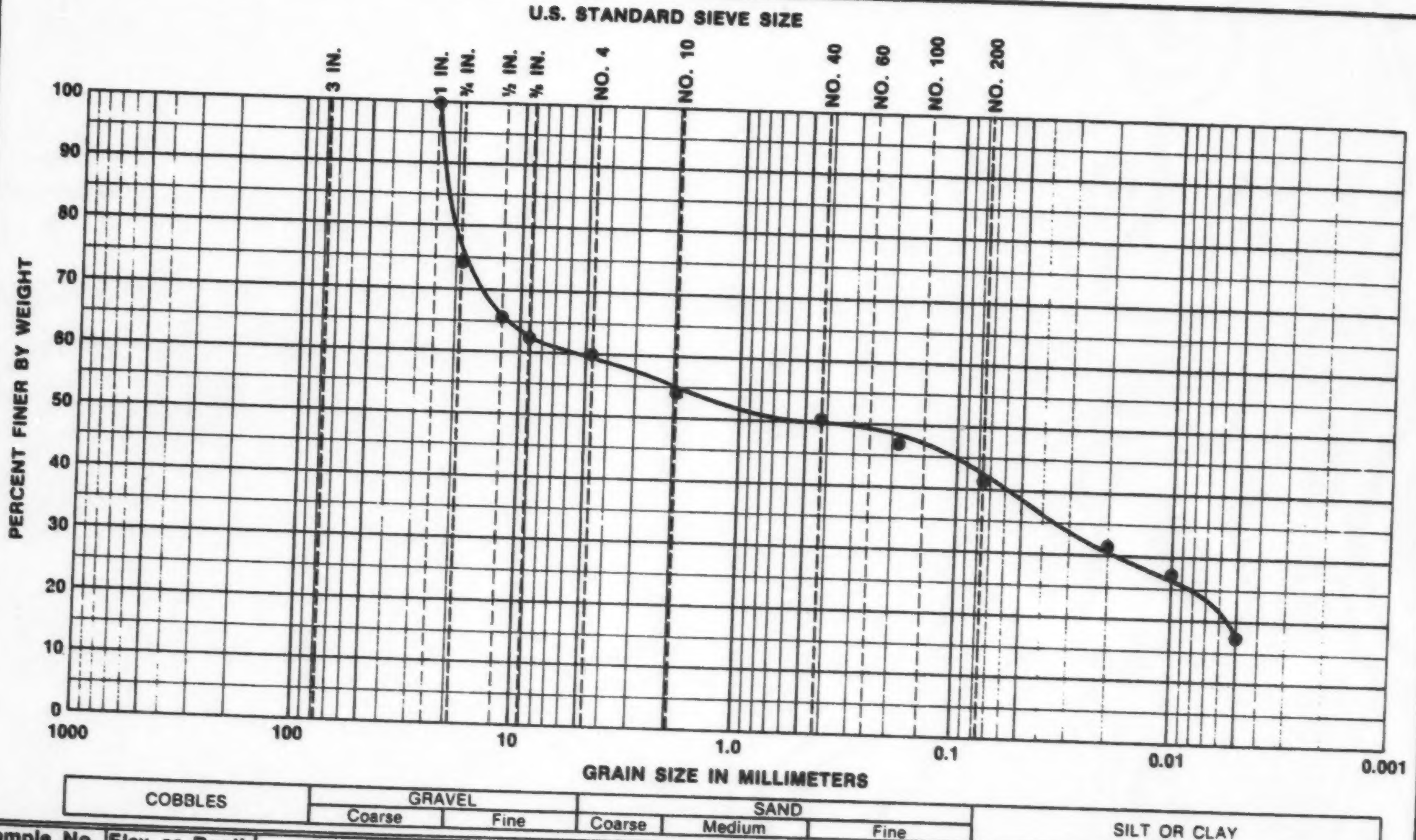
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

Figure B-30. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu1-6 | 7.16-7.62 | GC | 18.9 | 26 | 18 | 8 | |

GRADATION CURVES

**SKELLY AND LOY**
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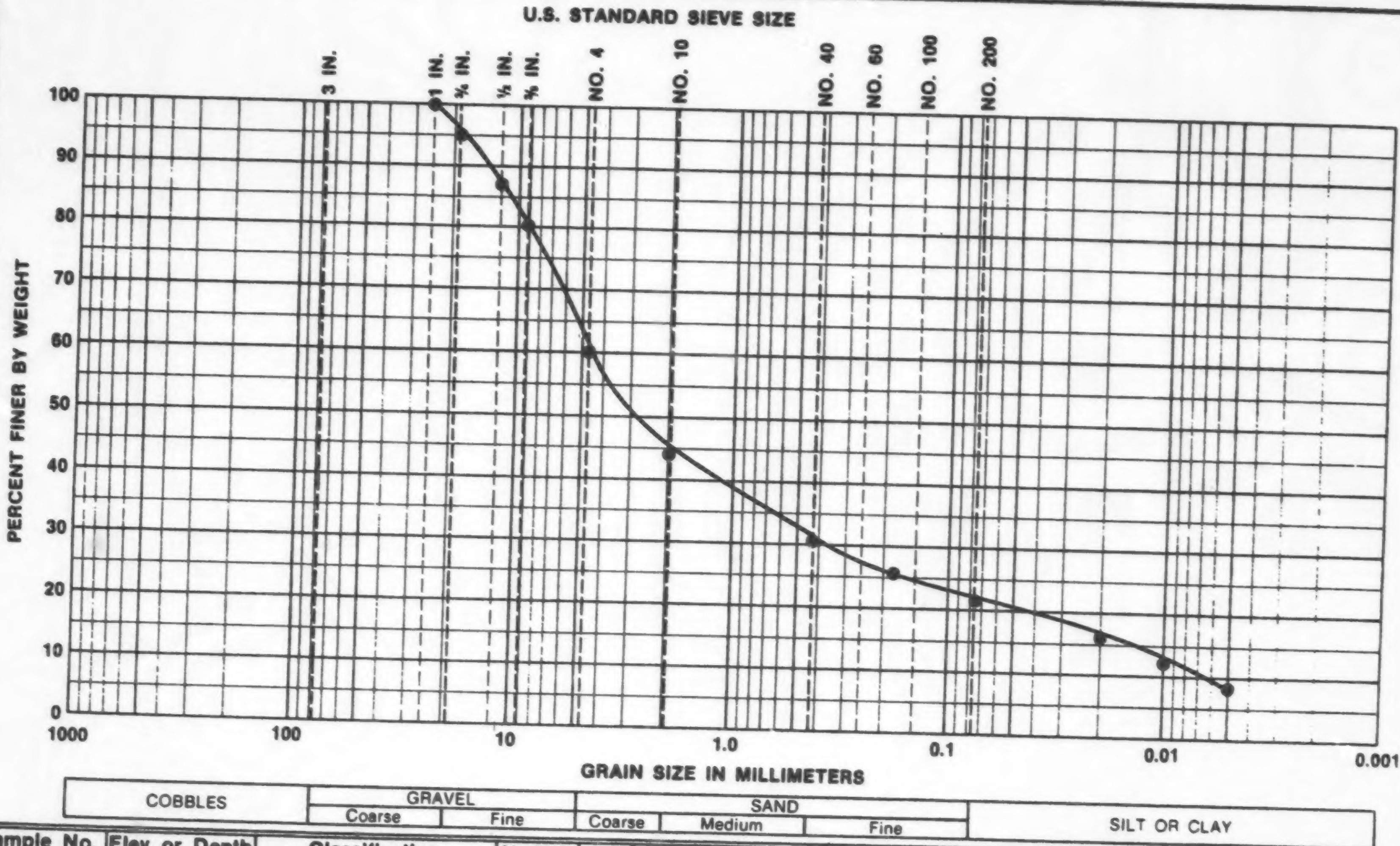
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

Figure B-31. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu2-2 | 1.07-1.52 | GC | 8.6 | 24 | 16 | 8 | |

**GRADATION CURVES**

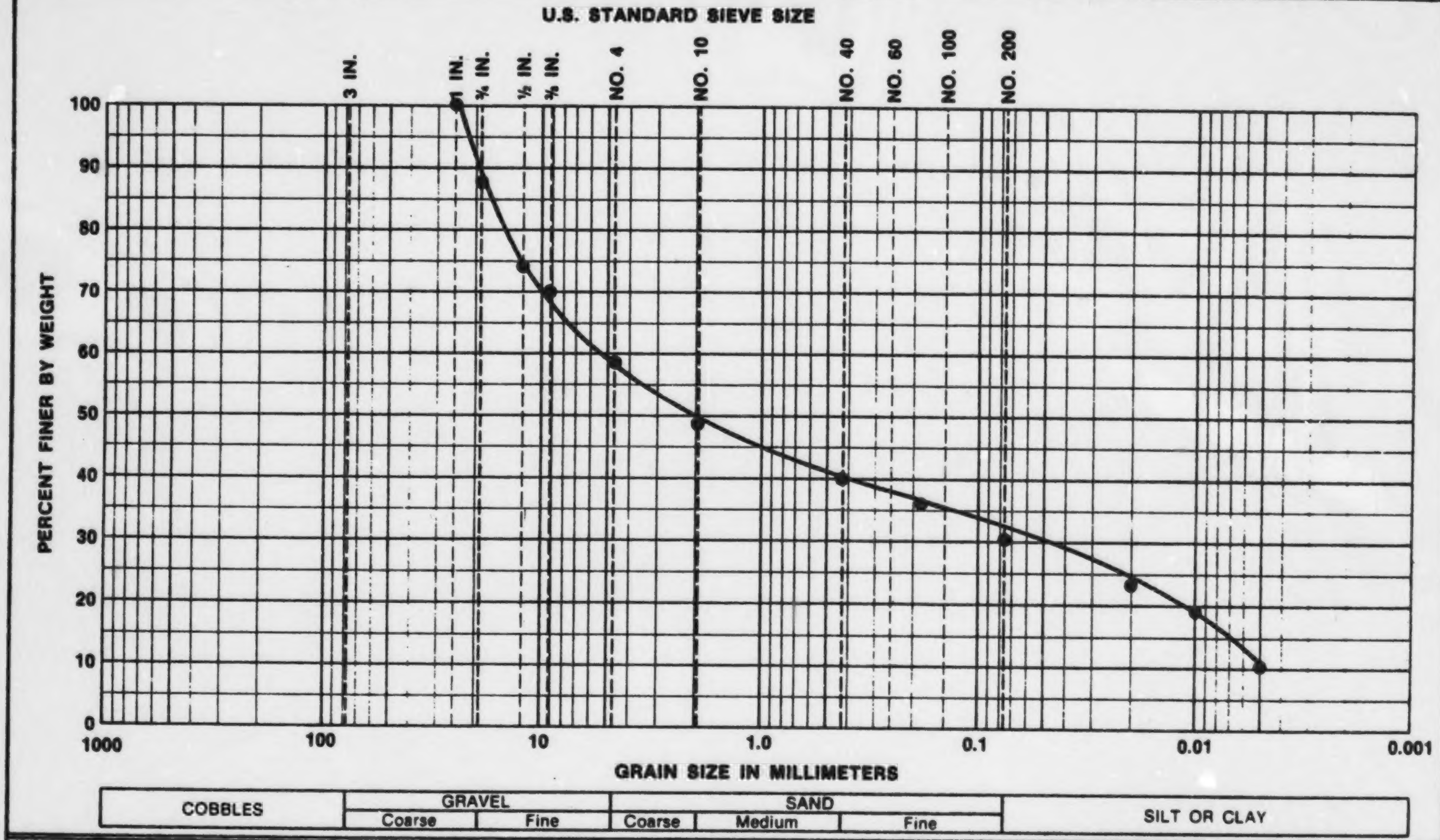
**SKELLY AND LOY**
Engineers-Consultants
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

| Date | Made By | Chkd By |
|---|---|---|
| 9/80 | DB | EML |

Figure B-32. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu2-9 | 11.73-12.19 | GW | 15.4 | 25 | 19 | 6 | |

**GRADATION CURVES**

**SKELLY AND LOY**
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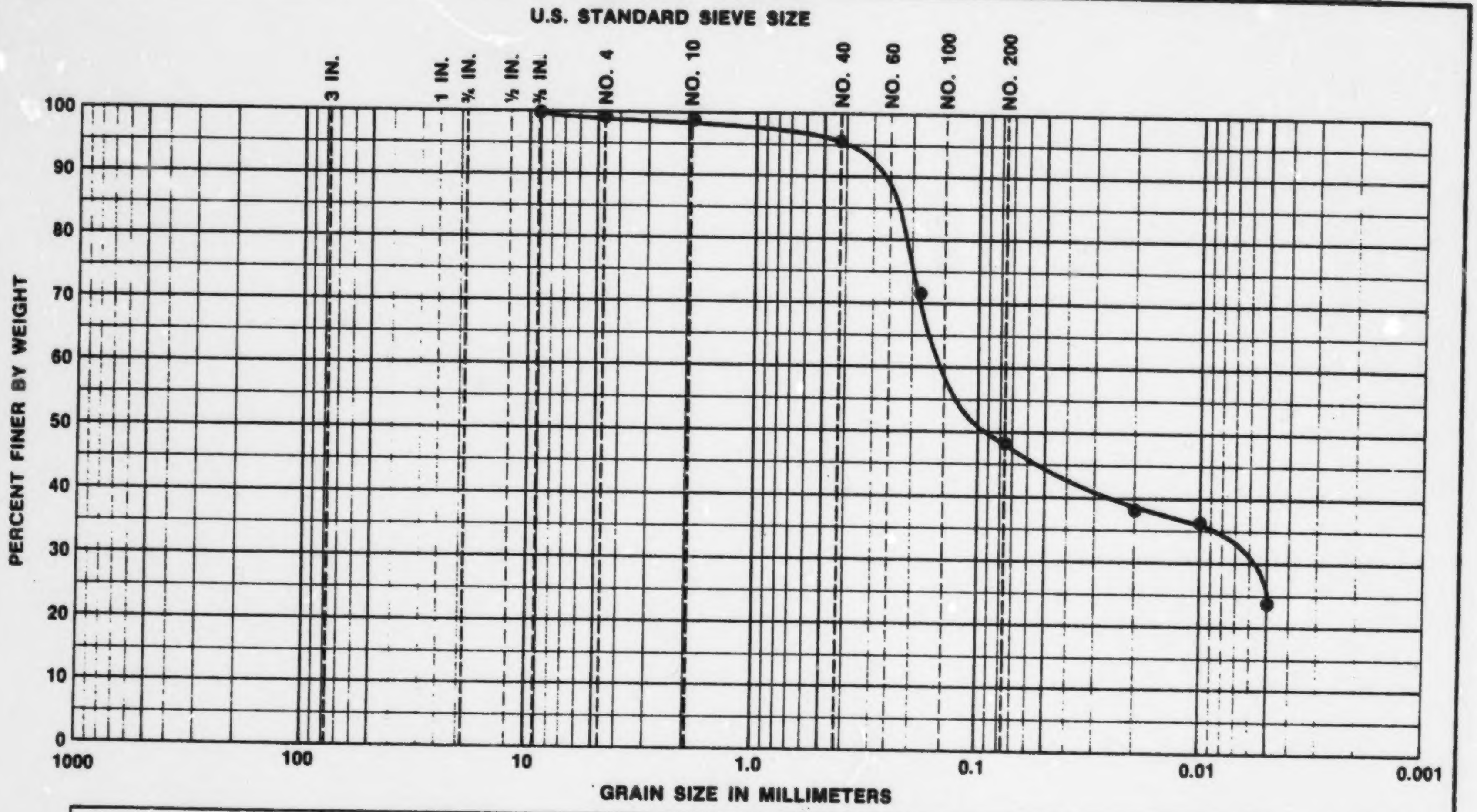
Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

Date 9/80 Made By DB Chkd By EML

Figure B-33. Gradation curves.



| COBBLES | GRAVEL |  | SAND |  |  | SILT OR CLAY |
|---|---|---|---|---|---|---|
|  | Coarse | Fine | Coarse | Medium | Fine |  |

| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu2-18 | 28.5-28.96 | SM-SC | 21.6 | 24 | 19 | 5 |  |

**GRADATION CURVES**

**SKELLY AND LOY**
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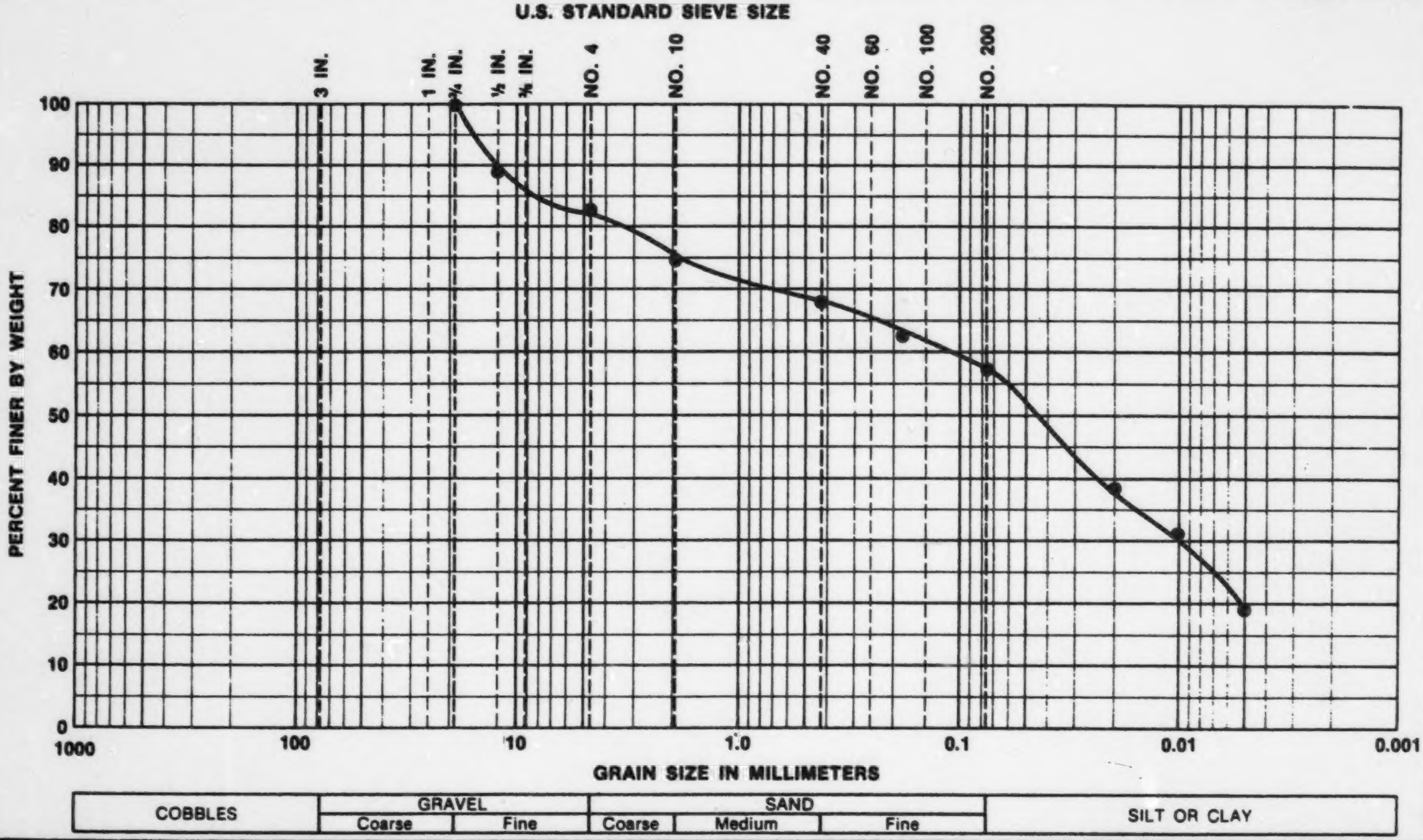
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

| Date | 9/80 | Made By | DB | Chkd By | EML |
|---|---|---|---|---|---|

Figure B-34. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu3-2 | 1.07-1.52 | CL-ML | 15.5 | 26 | 19 | 7 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**GRADATION CURVES**

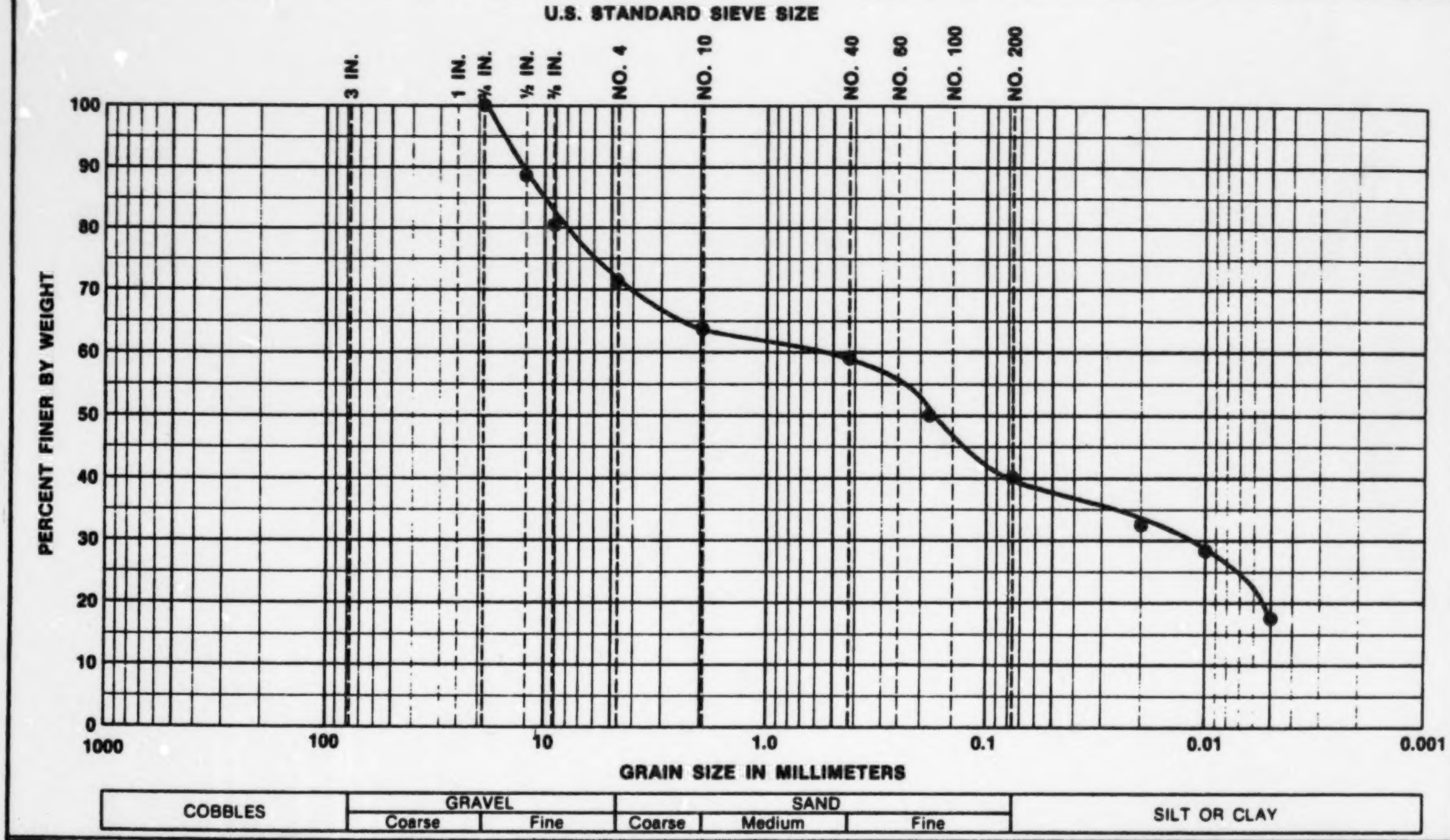
**SKELLY AND LOY**
**Engineers-Consultants**
**Harrisburg, Pennsylvania**

Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

Date 9/80 Made By DB Chkd By EML

Figure B-35. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu3-9 | 11.73-12.19 | SC | 14.6 | 25 | 17 | 8 | |

**GRADATION CURVES**

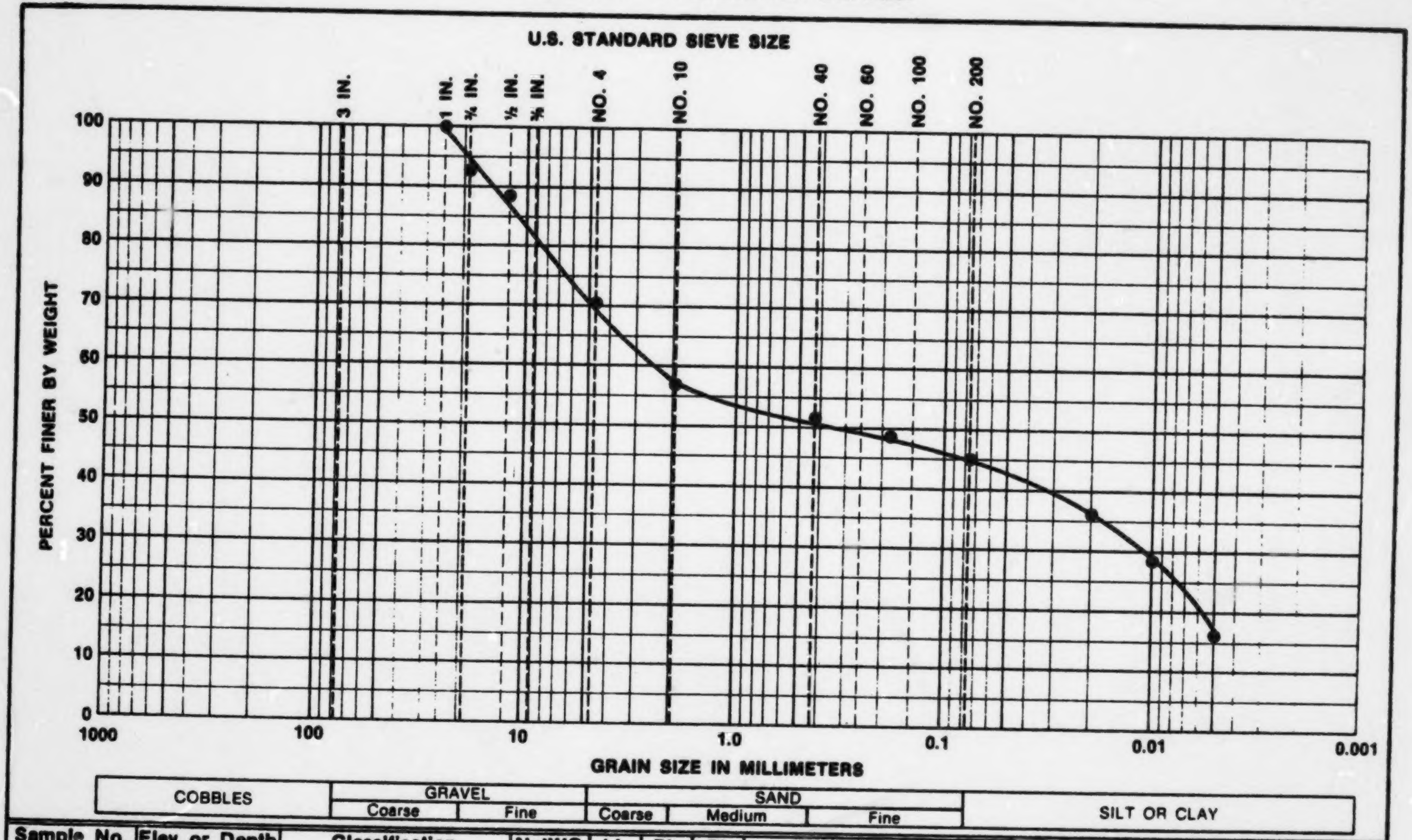
**SKELLY AND LOY**
**Engineers-Consultants**
**Harrisburg, Pennsylvania**

Project: Env. Assess. of Mng. Methods

Location: Perry County, Kentucky

| Date | 9/80 | Made By | DB | Chkd By | EML |
|---|---|---|---|---|---|

Figure B-36. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu3-13 | 20.87-21.33 | GC | 11.3 | 27 | 19 | 8 | |

**GRADATION CURVES**

**SKELLY AND LOY**
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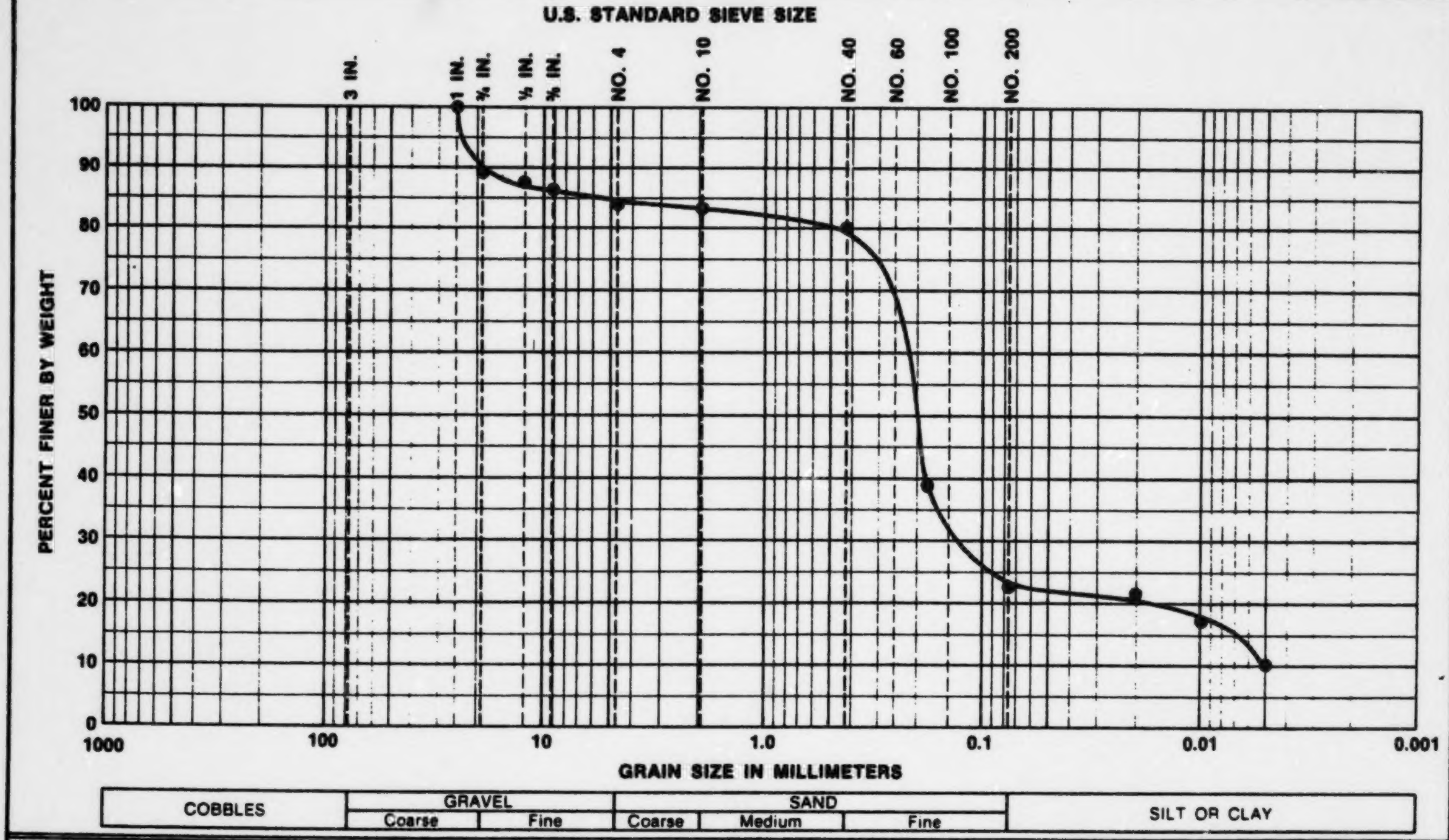
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

Figure B-37. Gradation curves.



| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu4-3 | 2.59-3.04 | SP | 11.9 | NP | NP | NP | |

## GRADATION CURVES

**SKELLY AND LOY**
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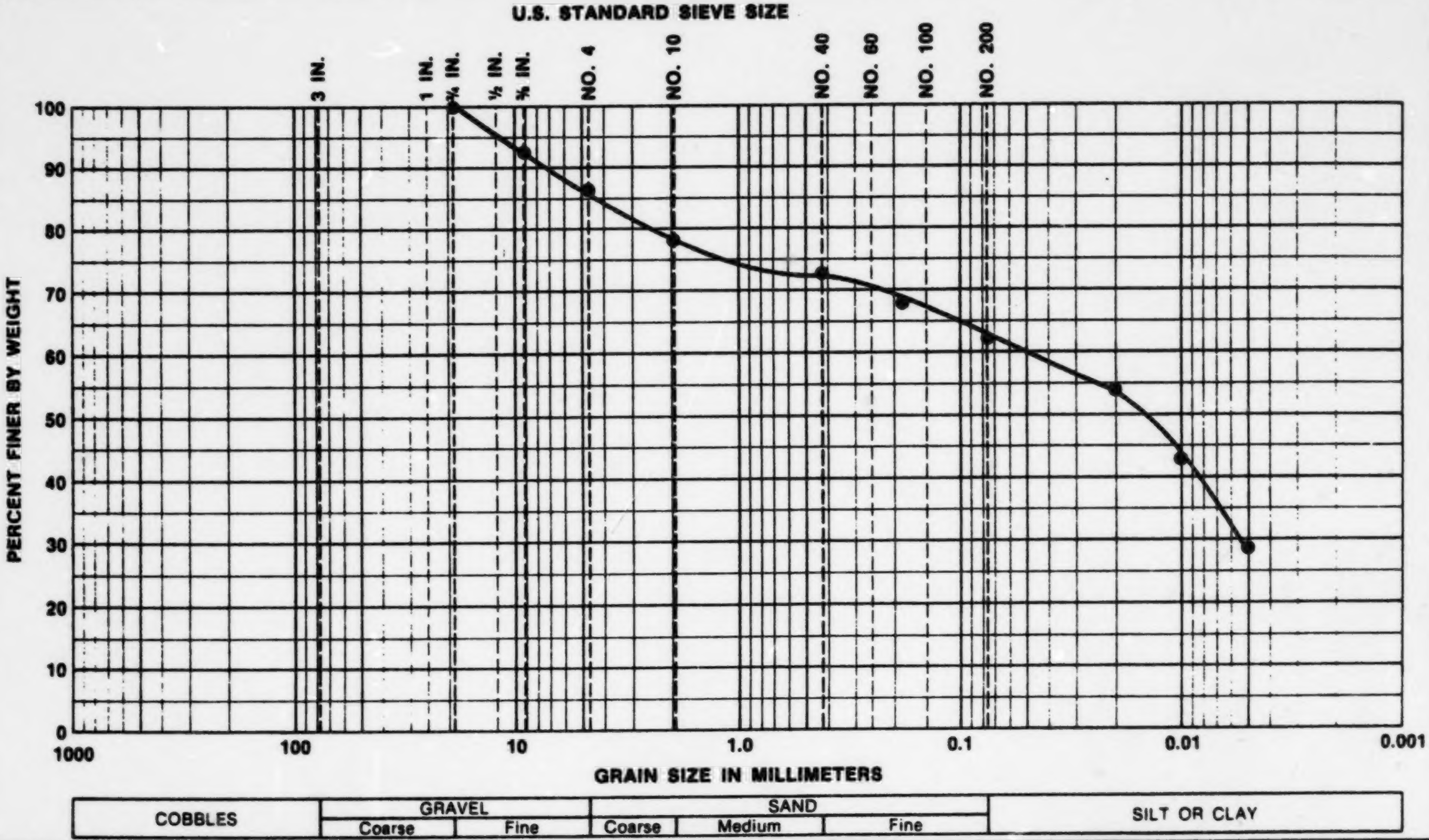
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

## Figure B-38. Gradation curves.



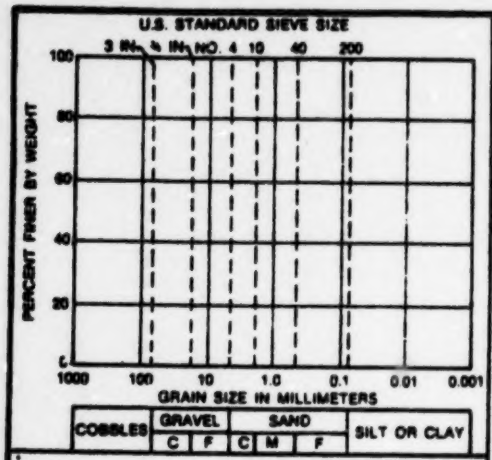
| Sample No. | Elev or Depth | Classification | NatWC | LL | PL | PI | REMARKS: |
|---|---|---|---|---|---|---|---|
| Bu4-8 | 10.21-10.66 | CL | 18.1 | 23 | 19 | 4 | |

**GRADATION CURVES**

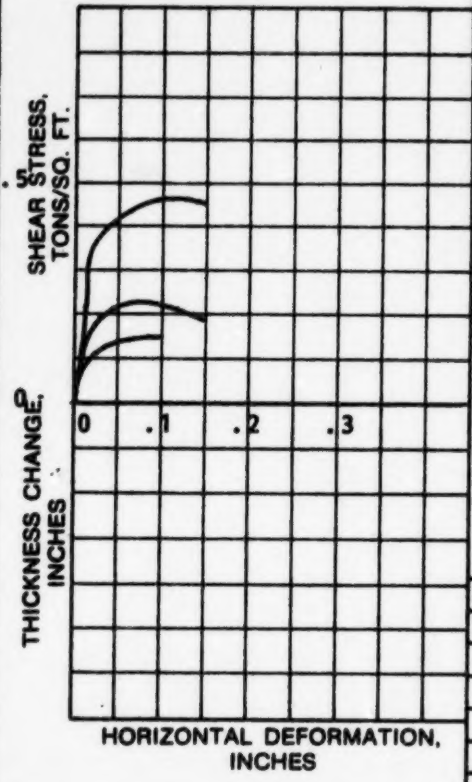
**SKELLY AND LOY**
Engineers-Consultants
Harrisburg, Pennsylvania

Project: Env. Assess. of Mng. Methods
Location: Perry County, Kentucky
Date 9/80 Made By DB Chkd By EML

Figure B-39. Direct shear test report.

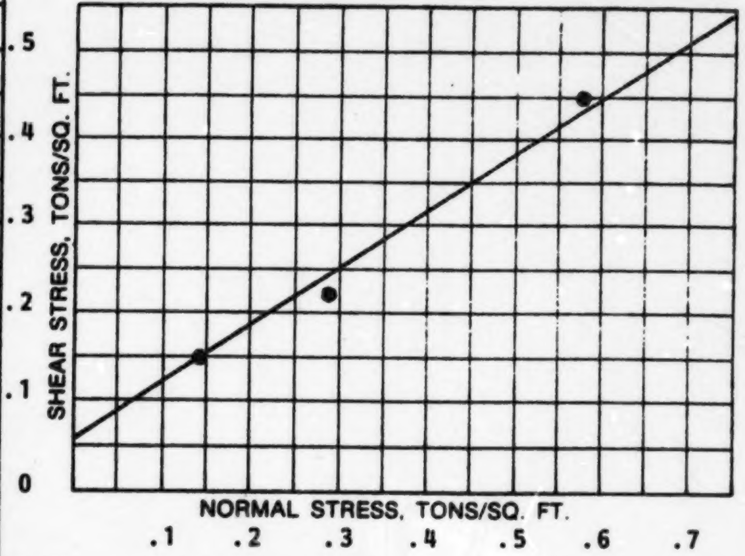


| | | | |
|---|---|---|---|
| Classification | | | |
| LL | Sp. G. | | |
| PL | D₁₀ | | |
| Test No. | 1 | 2 | 3 |
| Initial Water Content, Wo% | 8.7 | 8.7 | 8.7 |
| Dry Density Lbs./Cu. Ft. | 120.8 | 120.8 | 120.8 |
| Void Ratio, $e_o$ | .37 | .37 | .37 |
| Saturation $S_o$ % | 62 | 62 | 62 |
| Duration of Test | | | |
| WC after Test $W_f$ % | 14.5 | 14.1 | 13.8 |
| Normal Stress $\sigma$ T/Sq.Ft. | .146 | .292 | .584 |
| Max. Shear Stress $\tau$ T/Sq.Ft. | .15 | .22 | .45 |
| | | | |
| | | | |



| | |
|---|---|
| Type of Test | Type of Specimen |
| Strain —Control | Remolded |
| Consolidated | 2.5 in. diameter square |
| Drained | 1 in. thickness |

| SHEAR VALUES | ø | TAN ø | C,T/SQ. FT. |
|---|---|---|---|
| Maximum | 32° | 0.62 | 0.06 |
| Ultimate | | | |



Remarks: *Initial dry density was 120.8 pcf for all three specimens.

Natural overburden.

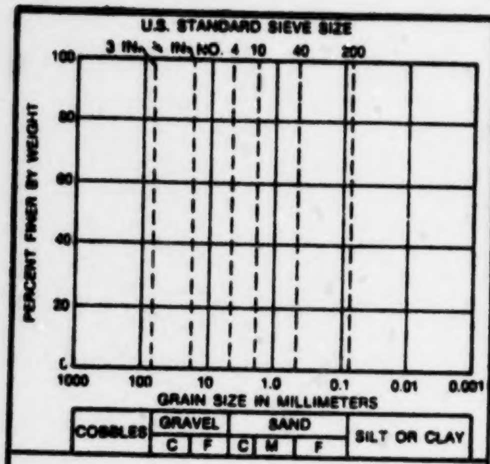
Project Environmental Assessment of Surface Mining Methods

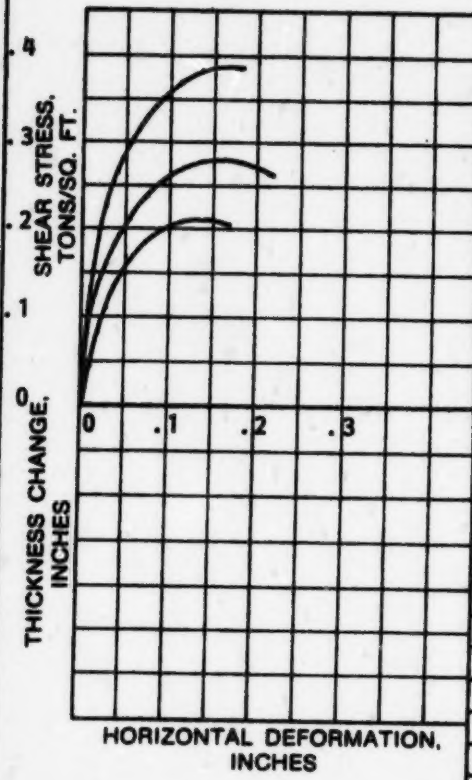
Area Kanawha County, W. Va.

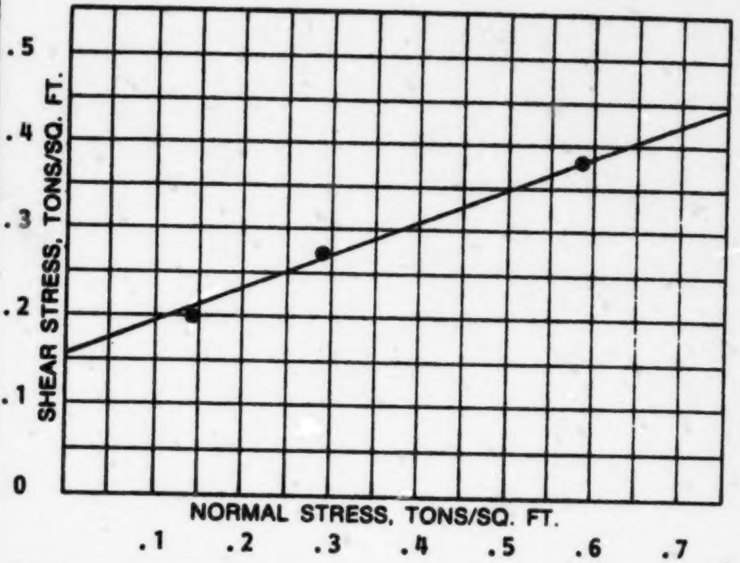
| | |
|---|---|
| Boring No. Sp. Grp. 1 | Sample No. |
| Elev. or Depth | Date Oct. 1980 |

**DIRECT SHEAR TEST REPORT**

Figure B-40. Direct shear test report.







| | | | |
|---|---|---|---|
| Classification | | | |
| LL | Sp. G. | | |
| PL | $D_{10}$ | | |
| Test No. | 1 | 2 | 3 |
| Initial Water Content, Wo% | 17.2 | 17.2 | 17.2 |
| Dry Density Lbs./Cu. Ft. | 106 | 106 | 106 |
| Void Ratio, $e_o$ | .56 | .56 | .56 |
| Saturation $S_o$ % | 82 | 82 | 82 |
| Duration of Test | | | |
| WC after Test $W_f$ % | 18.1 | 17.2 | 16.6 |
| Normal Stress σ T/Sq. Ft. | .146 | .292 | .584 |
| Max. Shear Stress τ T/Sq. Ft. | .20 | .27 | .38 |
| | | | |
| | | | |

| | |
|---|---|
| Type of Test<br>Strain —Control<br>Consolidated<br>Drained | Type of Specimen<br>Remolded<br>2.5 diameter in. square<br>1 in. thickness |

| SHEAR VALUES | ø | TAN ø | C,T/SQ. FT. |
|---|---|---|---|
| Maximum | 21° | 0.38 | 0.16 |
| Ultimate | | | |

Remarks: Fill material.

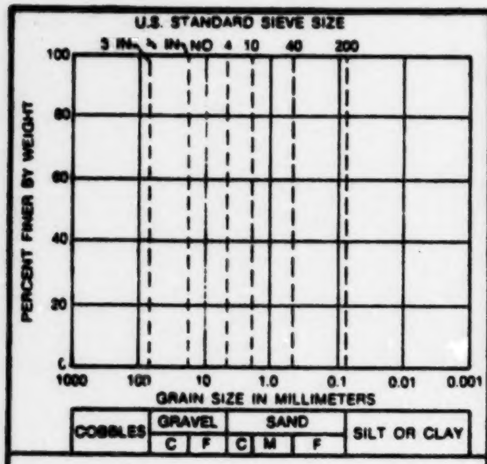
Project Environmental Assessment of Surface Mining Methods

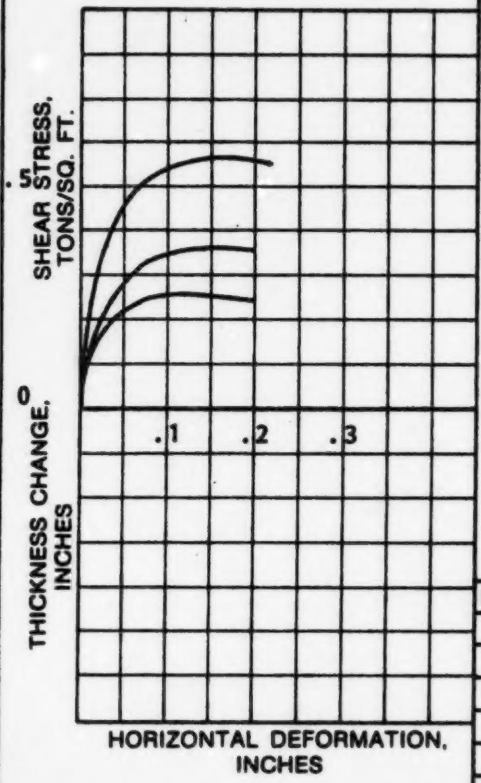
Area Kanawha County, W. Va.

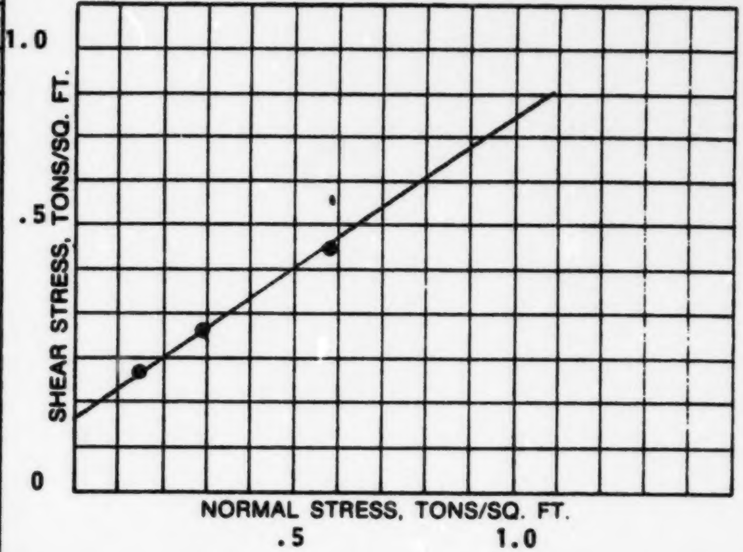
| | |
|---|---|
| Boring No. Sp. Grp. 5 | Sample No. |
| Elev. or Depth | Date Oct. 1980 |

**DIRECT SHEAR TEST REPORT**

Figure B-41. Direct shear test report.







Classification

| | |
|---|---|
| LL | Sp. G. |
| PL | $D_{10}$ |

| Test No. | 1 | 2 | 3 |
|---|---|---|---|
| Initial Water Content, Wo% | 17.1 | 17.1 | 17.1 |
| Dry Density Lbs./Cu. Ft. | 113 | 113 | 113 |
| Void Ratio, $e_o$ | .46 | .46 | .46 |
| Saturation $S_o$ % | 98 | 98 | 98 |
| Duration of Test | | | |
| WC after Test $W_f$ % | 17.1 | 17.4 | 16.8 |
| Normal Stress $\sigma$ T/Sq. Ft. | .146 | .292 | .584 |
| Max. Shear Stress $\tau$ T/Sq.Ft. | .27 | .37 | .56 |
| | | | |
| | | | |

| Type of Test | Type of Specimen |
|---|---|
| Strain —Control | Remolded |
| Consolidated | 2.5 in. diameter square |
| Drained | 1 in. thickness |

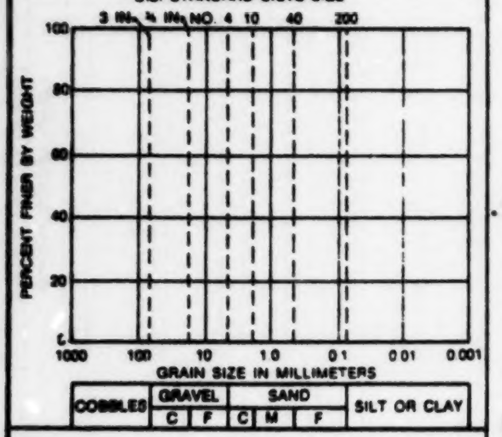
| SHEAR VALUES | ø | TAN ø | C,T/SQ. FT. |
|---|---|---|---|
| Maximum | 36° | 0.73 | 0.14 |
| Ultimate | | | |

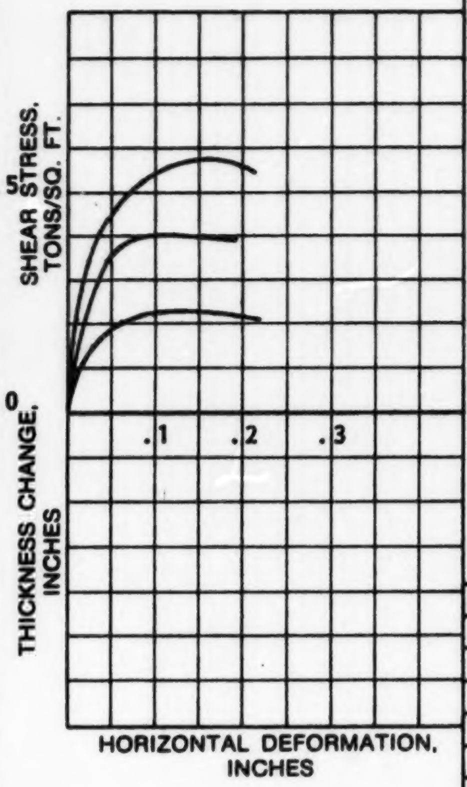
Remarks: Natural overburden.

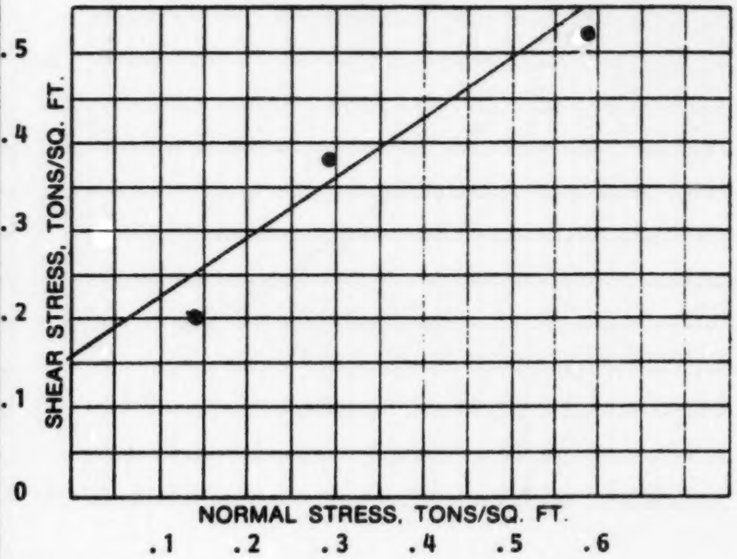
| | |
|---|---|
| Project Environmental Assessment of Surface Mining Methods | |
| Area Perry County, Kentucky | |
| Boring No. B. Grp. 7 | Sample No. |
| Elev. or Depth | Date Sept. 1980 |

**DIRECT SHEAR TEST REPORT**

Figure B-42. Direct shear test report.







| | |
|---|---|
| Classification | |
| LL | Sp. G. |
| PL | $D_{10}$ |

| Test No. | 1 | 2 | 3 |
|---|---|---|---|
| Initial Water Content, Wo% | 17.7 | 17.7 | 17.7 |
| Dry Density Lbs./Cu. Ft. | 110 | 110 | 110 |
| Void Ratio, $e_o$ | .502 | .502 | .502 |
| Saturation $S_o$ % | 94 | 94 | 94 |
| Duration of Test | | | |
| WC after Test $W_f$ % | 16.0 | 15.8 | 15.9 |
| Normal Stress $\sigma$ T/Sq. Ft. | .146 | .292 | .584 |
| Max. Shear Stress $\tau$ T/Sq.Ft. | .20 | .38 | .52 |
| | | | |
| | | | |

| Type of Test | Type of Specimen |
|---|---|
| Strain —Control | Remolded |
| Consolidated | 2.5 in. diameter<br>in. square |
| Drained | 1 in. thickness |

| SHEAR VALUES | ø | TAN ø | C,T/SQ. FT. |
|---|---|---|---|
| Maximum | 34.5° | 0.68 | 0.16 |
| Ultimate | | | |

Remarks: Spoil material.

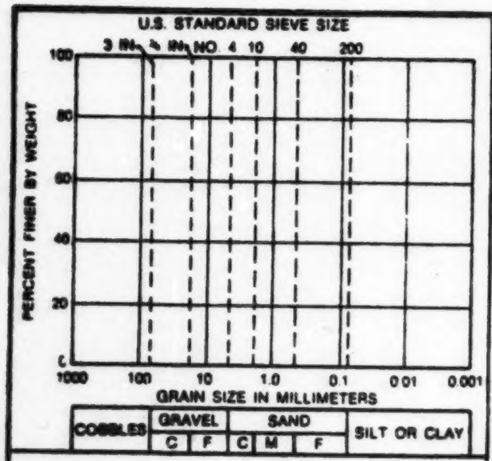
Project Environmental Assessment of Surface Mining Methods

Area Perry County, Kentucky

| | |
|---|---|
| Boring No. B. Grp. 2 | Sample No. |
| Elev. or Depth | Date Sept. 1980 |

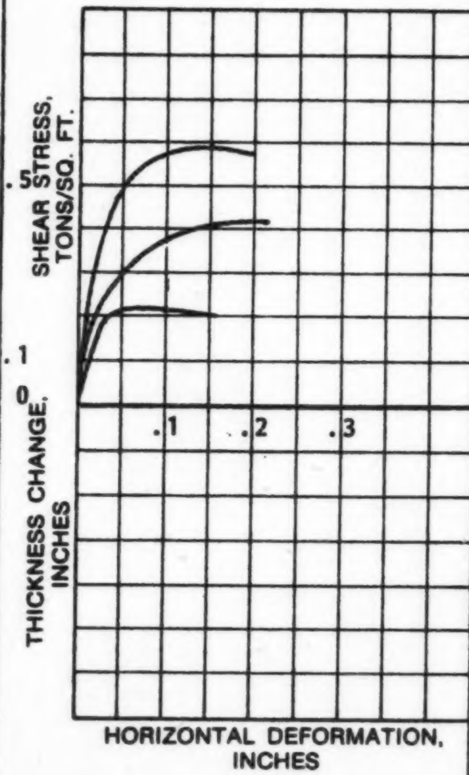
**DIRECT SHEAR TEST REPORT**

Figure B-43. Direct shear test report.



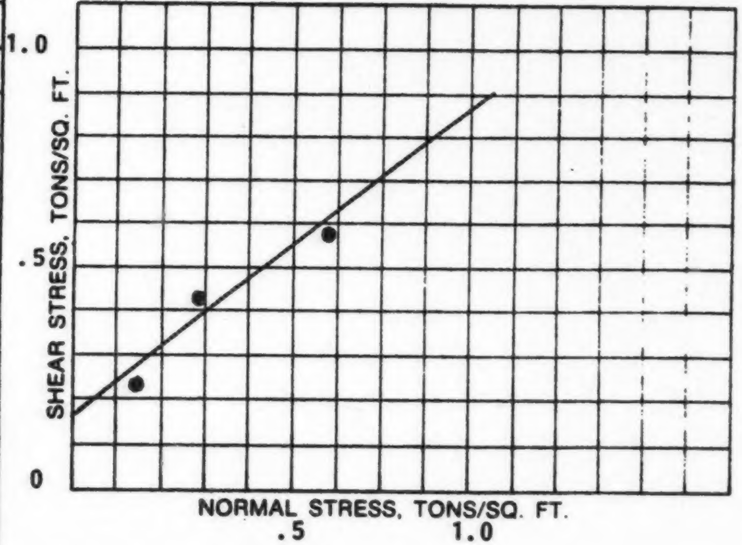
Classification

| | | | |
|---|---|---|---|
| LL | Sp. G. | | |
| PL | $D_{10}$ | | |
| Test No. | 1 | 2 | 3 |
| Initial Water Content, Wo% | 14.6 | 14.6 | 14.6 |
| Dry Density Lbs./Cu. Ft. | 113 | 113 | 113 |
| Void Ratio, $e_o$ | .46 | .46 | .46 |
| Saturation $S_o$ % | 83 | 83 | 83 |
| Duration of Test | | | |
| WC after Test $W_f$ % | 16.5 | 15.8 | 15.8 |
| Normal Stress σ T/Sq.Ft. | .146 | .292 | .584 |
| Max. Shear Stress τ T/Sq.Ft. | .23 | .42 | .58 |
| | | | |
| | | | |



| Type of Test | Type of Specimen |
|---|---|
| Strain —Control | Remolded |
| Consolidated | 2.5 diameter in. square |
| Drained | 1 in. thickness |

| SHEAR VALUES | ø | TAN ø | C,T/SQ. FT. |
|---|---|---|---|
| Maximum | 39° | 0.81 | 0.16 |
| Ultimate | | | |



Remarks: Natural overburden.

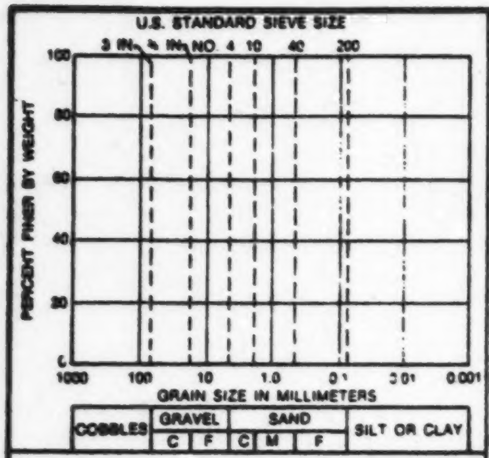
Project Environmental Assessment of Surface Mining Methods

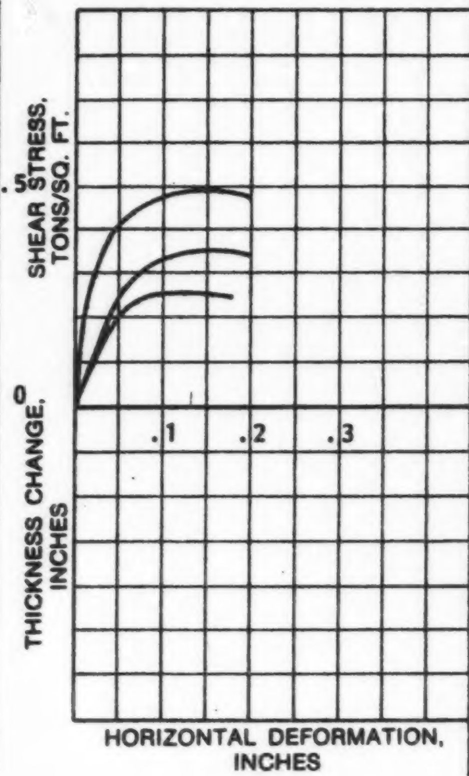
Area Perry County, Kentucky

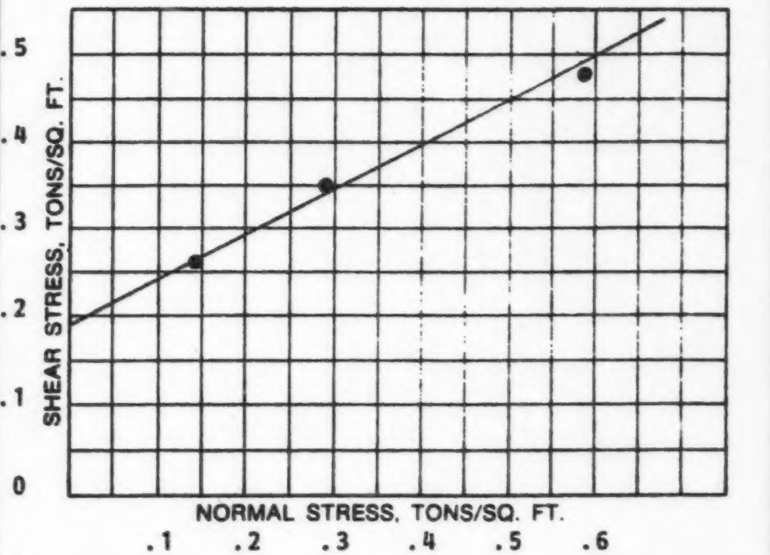
| | |
|---|---|
| Boring No. Bu. Grp. 1 | Sample No. |
| Elev. or Depth | Date Sept. 1980 |

DIRECT SHEAR TEST REPORT

Figure B-44. Direct shear test report.







| | | | |
|---|---|---|---|
| Classification | | | |
| LL | Sp. G. | | |
| PL | $D_{10}$ | | |
| Test No. | 1 | 2 | 3 |
| Initial Water Content, Wo% | 16.5 | 16.5 | 16.5 |
| Dry Density Lbs./Cu. Ft. | 113 | 113 | 113 |
| Void Ratio, $e_o$ | .46 | .46 | .46 |
| Saturation $S_o$ % | 95 | 95 | 95 |
| Duration of Test | | | |
| WC after Test $W_f$ % | 16.5 | 15.9 | 15.6 |
| Normal Stress σ T/Sq.Ft. | .146 | .292 | .584 |
| Max. Shear Stress τ T/Sq.Ft. | .26 | .35 | .48 |
| | | | |
| | | | |

| | |
|---|---|
| Type of Test<br>Strain —Control | Type of Specimen<br>Remolded |
| Consolidated | 2.5 diameter in. square |
| Drained | 1 in. thickness |

| SHEAR VALUES | ø | TAN ø | C,T/SQ. FT. |
|---|---|---|---|
| Maximum | 27.5 | 0.52 | 0.19 |
| Ultimate | | | |

Remarks: Fill material.

| | |
|---|---|
| Project Environmental Assessment of Surface Mining Methods | |
| Area Perry County, Kentucky | |
| Boring No. Bu. Grp. 3 | Sample No. |
| Elev. or Depth | Date Sept. 1980 |

DIRECT SHEAR TEST REPORT